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U.S. FISH AND WILDLIFE SERVICE

REGION 6

CONTAMINANTS PROGRAM

CONTAMINANT PATHWAYS AT QUIVIRA NATIONAL WILDLIFE REFUGE 1996

by

Susan H. Blackford

DEC ID: 199660002
Project ID: 1261-6N33

U.S. FISH AND WILDLIFE SERVICE
Kansas Field Office
Manhattan, Kansas
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Kansas Field Office
315 Houston Street, Suite E
Manhattan, Kansas 66502-6172

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EXECUTIVE SUMMARY

This study was undertaken to assess several contaminant concerns at Quivira National Wildlife Refuge (Quivira). The objectives of this project were (1) to determine if agricultural chemicals are present in waters entering Quivira, (2) to determine the extent petroleum hydrocarbon contamination from oil extraction activities on Quivira, (3) determine if selenium is present at Quivira in concentrations of concern, and (4) determine if other inorganic or organic contaminants are found at levels of concern in foods of interior least terns and snowy plovers.

The investigation found that contamination does not appear to be widespread at Quivira. However, several compounds and trace elements were detected at elevated concentrations in only one or two samples. One composite forage fish sample contained elevated concentrations of arsenic, copper, and lead. Aromatic hydrocarbon indices suggest that petrogenic contamination of soils is occurring at Quivira and particularly around one group of oil production facilities. Elevated concentrations of selenium were detected in water samples taken throughout the summer at one site.

Triazine compounds, including atrazine, could be a serious concern for Quivira due to the frequency of detection of triazines in surface water samples and the potential for effects, at low concentrations, to amphibians. However, more detailed work would be needed to evaluate this situation.

Although endrin was detected in seventy-one percent of the invertebrate samples it was found at low concentrations. We do not believe that at the concentrations detected in this study that endrin is a concern for Quivira. However, endrin is more toxic to fish than to invertebrates and can accumulate rapidly in fish exposed through food sources.

Although it is unlikely that the concentrations of the organic compounds and trace elements detected in the samples are high enough to cause direct mortality, they could be causing detrimental effects through the long term exposure or from the combination of several compounds and elements. It is difficult to make conclusions about the possible impacts to wildlife based on the limited sampling effort for this study. More comprehensive sampling in areas where elevated concentrations were found might reveal the spatial distribution and level of occurrence of the compounds and elements.

The largest reductions in pesticide levels on the Refuge might be gained from working with landowners in the Rattlesnake Creek Watershed to reduce the amounts of pesticides

used on crops and to establish buffers along the streams and wetlands in the Watershed to reduce the amount of pesticides entering the water. Refuge Staff should continue to inspect the oil production facilities and work to prevent spill and initiate quick cleanup of any spills. A more comprehensive investigation of groundwater should be initiated to determine if groundwater is contributing selenium and other trace elements to the Refuge.

ABBREVIATIONS AND CONVERSION FACTORS

Abbreviations

micrograms per gram ..... µg/g
micrograms per kilogram ..... µg/kg
micrograms per liter ..... µg/l
milligrams per kilogram ..... mg/kg

Conversions

micrograms per gram = parts per million (ppm)
milligrams per kilogram = parts per million (ppm)
micrograms per kilogram = parts per billion (ppb)
micrograms per liter = parts per billion (ppb)

ACKNOWLEDGMENTS

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Larry Gamble and Patty Stevens coordinated project funding and sample submission. George Allen, Larry Gamble, Pedro Ramirez, David Hilley, and John Meisner provided valuable reviews of this report.

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INTRODUCTION

Quivira National Wildlife Refuge (Quivira) supports a variety of nesting, migrating, and wintering bird species, and is a major stopover point for migratory birds in the Central Flyway. In May 2002, Quivira was designated a Ramsar "Wetland of International Importance." Quivira is one of three nesting locations in Kansas for least terns (*Sterna antillarum*), which are federally listed as endangered. The endangered whooping cranes (*Grus americana*) usually stop at the refuge during spring and fall migrations. Quivira is also important for numerous species of migrating shorebirds including snowy plovers (*Charadrius alexandrinus nivorsus*). Raptors, including wintering bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons *(Falco peregrinus*), are attracted to Quivira due to the numerous waterfowl and shorebirds. Management goals for Quivira emphasize wetlands areas for nesting by shorebirds and maintenance of moist soil areas for food for migrating birds.

In addition, many resident mammal, reptile, fish, bird, and amphibian species, including game species, inhabit Quivira year round. In 1991 the Arkansas darter *(Etheostoma cragini)*, a State of Kansas threatened species and a federal candidate species, were found in pools fed by naturally-flowing springs southwest of the Big Salt Marsh. At least one black-tailed prairie dog (*Cynomys ludovicianus*) colony currently exists on Quivira and others are found on private land bordering the Refuge.

Numerous oil production facilities were in place when Quivira was purchased as a refuge in 1995, thus some contaminant concerns relate to the oil production and storage activities on and nearby the refuge. Though the Service owns surface rights to Quivira lands some of the mineral rights were not conveyed with the surface rights and remain privately owned. Oil production has continued since the Refuge was purchased and some new production facilities have been developed. In addition, some wells are not currently producing and others have been converted to other uses. The Eriksen well was plugged in 1996. The Fair B-5 well is inactive. The Wolf A-1 and Fair B wells have been converted to salt disposal wells. There have been many releases of petroleum products on and near the refuge. There was a spill at the Sleeper 1 well in 1998, several spills from pipelines around the tank batteries, and several spills from transport pipelines that run through the refuge. Most recently, a pipeline was broken less than a mile north of Quivira in 2003. Quivira's staff currently monitor all oil production faculties monthly.

Water for most of the Refuge is diverted from Rattlesnake Creek, so the quality and quantity of ground water and surface water in the Rattlesnake Creek watershed are also a

management concern at Quivira. Use of surface waters for irrigation in Rattlesnake Creek outstripped supply more than 25 years ago (Sophocleous 1992). In addition, pumping of ground water for irrigation has increased dramatically in the past 20 years, and "extensive ground-water appropriations in the Great Bend Prairie have contributed to extremely low flows in the Arkansas River and Rattlesnake Creek" (Sophocleous 1992). Associated with the low surface flows and declining ground water levels are intrusions of selenium, salt and minerals from strata below the freshwater aquifer (Sophocleous 1992). Therefore, over the long term, use of ground water for agricultural irrigation may have serious effects on selenium, salt and mineral concentrations in subsurface and surface waters on Quivira. Past monitoring efforts have documented elevated selenium concentrations in Rattlesnake Creek downstream from Quivira, in the Big Salt Marsh and in Salt Creek in the northeast corner of the Refuge (Kansas Department of Health and Environment 1986, Sophocleous and Perkins 1992). Salinity in the Big Salt Marsh and Little Salt Marsh has been affected in recent years by variable precipitation and increased use of ground water for irrigation.

Quivira is surrounded by agricultural lands on which agricultural chemicals are used. However, information on pesticides in the surface water flowing into Quivira is lacking. In addition, Quivira lies in a discharge area for the High Plains Aquifer which can also convey agricultural contaminants into the waters of Quivira (Sophocleous and Perkins 1993).

Our goals for this study were to gain information about selected agricultural chemicals entering Quivira through surface waters, evaluate selenium concentrations on Quivira, examine petroleum hydrocarbon contamination from the oil production facilities on Quivira, and determine if inorganic or organic contaminants are found at levels of concern in foods of interior least terns and snowy plovers.

We sampled surface water, terrestrial invertebrates, forage fish, and soils to evaluate potential contamination from agricultural chemical transport into the refuge and petroleum production on the refuge, selenium occurrence on the refuge, and potential elevated levels of elements in piping plover and least terns food items.

DESCRIPTION OF AREA

Quivira is located in the sand prairie area of Stafford, Rice, and Reno counties in south-central Kansas. At the time of this investigation, Quivira encompassed approximately

8822 hectares (ha) (Figure 1). The terrain is generally flat, but broken by stabilized sand dunes. The climate is considered mild and dry subhumid. Mean annual precipitation in Quivira area is about 61cm. Sub-zero temperatures usually only occur a few times each winter. Snowfall averages approximately 50 cm per year but there is seldom much snow accumulation. Temperatures above 32° C occur 50 days or more each summer. The growing season is approximately six months per year. The prevailing winds are southerly during the summer and northerly during the winter. Average wind velocities are moderately strong in all seasons and reach a maximum during the spring. Severe storms can develop suddenly.

The High Plains Aquifer is found beneath the western part of Kansas. Quivira lies in the eastern portion of the High Plains Aquifer underlying the Great Bend Prairie region. The High Plains Aquifer, which includes the Great Bend Prairie Aquifer, is the most important and extensively used aquifer in Kansas. Water in the aquifer flows in an east-northeast direction under a region that is intensively farmed and irrigated. The Great Bend Prairie region is covered with a veneer of loess deposits and sand dunes, with underlying Pleistocene alluvium forming the major aquifer of the area. The local alluvial aquifers typically contain large concentrations of dissolved solids, chlorides and nitrates which can result from the discharge of saline water from underlying bedrock, and contamination from oil fields and agricultural practices. These alluvial aquifers also can have large concentrations of sulfate, iron, manganese, selenium, and naturally occurring gross-alpha radioactivity (Stullken et al. 1987). The lower reaches of Rattlesnake Creek, which lie within Quivira, are a natural groundwater discharge area of both the Great Bend Prairie Aquifer and underlying bedrock aquifers (Sophocleous and Perkins 1993). Depth to ground water is less than 20 feet on Quivira. The ground water levels and surface water levels are greatly influenced by each other (Sophocleous and Perkins 1993). There are at least two artesian wells on Quivira.

Rattlesnake Creek is the major surface water transport into and through Quivira, gaining water as it travels through the refuge. It supplies most of the water to the Refuge. It enters Quivira on the southwest edge, runs north-northeast through Quivira, and flows into Salt Creek about one mile east of the Big Salt Marsh. Salt Creek begins northeast of Big Salt Marsh and flows easterly through Quivira about four miles exiting Quivira near the northeast corner of Quivira. Salt Creek joins the Arkansas River northeast of Quivira.

Water diverted from Rattlesnake Creek flows through canals with water control structures and into 32 impoundments. Many of the impoundment areas are managed as moist soil units, in which the water is drawn down to encourage plant production and then reflooded. Big Salt Marsh and Little Salt Marsh are important features of Quivira.

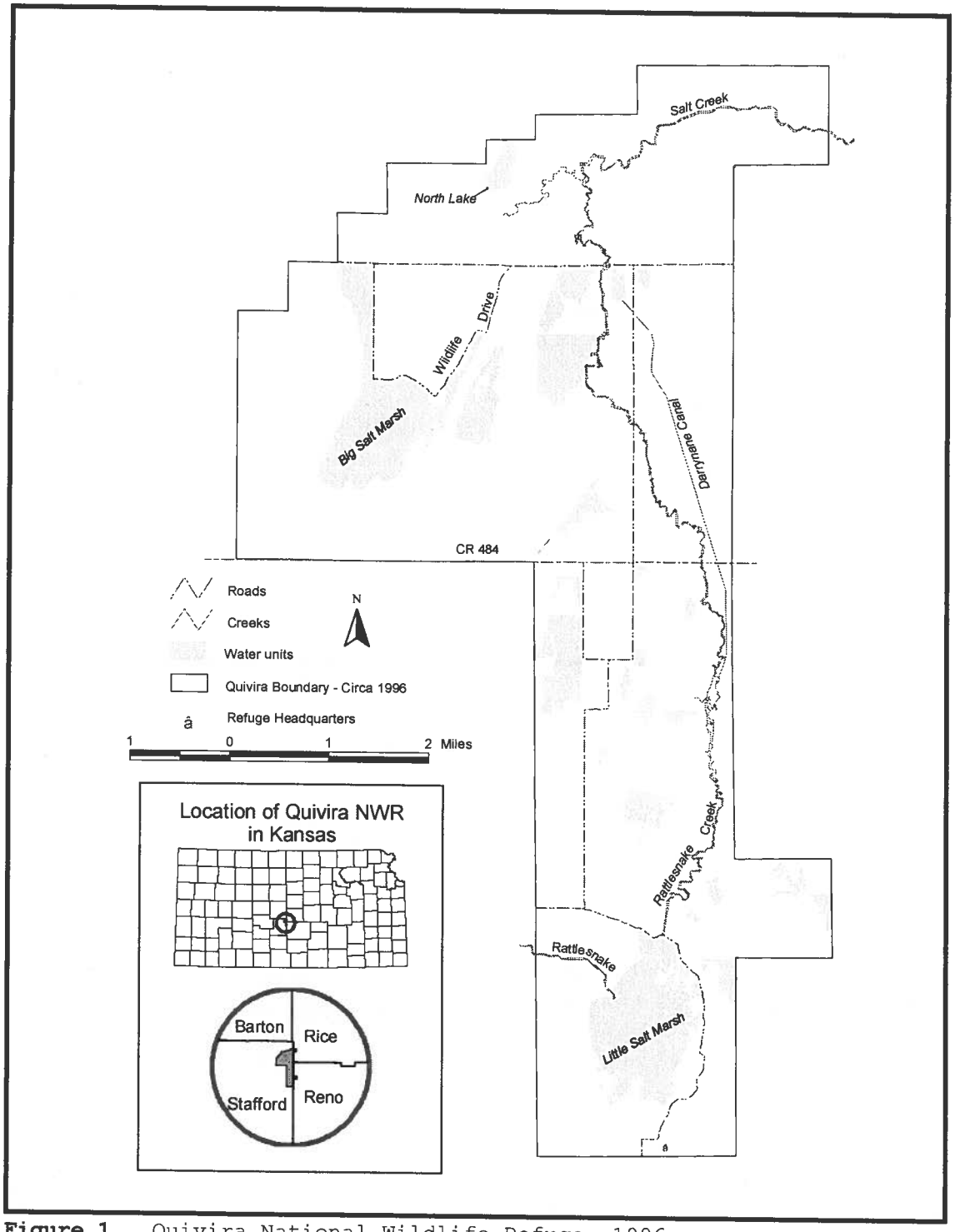

Figure 1. Quivira National Wildlife Refuge, 1996

Quivira habitats are primarily wet meadows, grassland, crop land, mudflats, woodlands, wetlands, shallow impoundments, and moist soil units. Most of the surrounding habitat along the creeks consists of grassland, although there are some cottonwood trees. Two exotic species, saltcedar (*Tamarisk* species) and Russian olive (*Elaeagnus angustifolia*), are invading some areas.

When Quivira was established in 1955 some of the mineral rights to the lands comprising Quivira were not conveyed with the surface rights. As a result oil production continues on portions of Quivira lands in the northern half of the refuge. Many are adjacent to marshes and water bodies, and often are only elevated above the water on soil pads. Production facilities consist of oil pumping wells, locally known as grasshopper wells, and storage tank batteries usually comprised of two to four connected storage tanks. Most of the wells and tanks are surrounded by berms for spill prevention and control. The majority of soil types found around the oil production facilities are generally classified as sandy clay loam which is associated with a high water table - usually a few centimeters to no more than 2 meters below the surface, flooding, ponding of surface water, and slow runoff. These conditions are observable on Quivira. The berms around the oil production facilities can hold water, especially following a precipitation event.

Quivira is one of three nesting areas in Kansas for the interior least tern. The terns nesting area is north of the Big Salt Marsh. The staff of Quivira have fenced the area to prevent predation and inadvertent human disturbance.

METHODS

Surface Water

We collected surface water from eight locations once a month, from April to October 1996. We sampled where water enters or exits Quivira and bodies of water on Quivira (Figure 2). We collected the water samples either by directly submerging the sample container into the water or by submerging a polyethylene dipper in the water to collect a sample and then transferring the sample into the sample container. The dipper was rinsed with distilled water after every use. The water samples were stored in 500 ml chemically-cleaned glass jars with teflon lined lids. Airspace in the jars was kept to a minimum. We transported the water samples on ice to the field lab which we set up in Quivira's environmental education building. The water samples were screened for pesticides within 24 hours using the Millipore test kits.

Pesticide concentrations and loads in surface waters vary greatly depending on rainfall timing, intensity, and amounts (Richards and Baker 1993). Peak herbicide concentrations in rivers of the Midwest can occur over days to weeks and may not be detected by a single monthly sample (Larson et al. 1997). Due to our monthly sampling frequency and inability to precisely time sampling with precipitation events, we probably did not detect the maximum concentrations that occurred during the sampling period. Our data also do not represent the full range or duration of these pesticide loads.

We used Millipore (P.O. Box 9125, Bedford, Massachusetts 01730-9125) EnviroGard™ Quanitube® kits for atrazine, 2,4-D, and alachlor to analyze the water samples for those and related compounds in the surface water. All analytical procedures followed the instructions for each system.

Millipore kit detection ranges. The Millipore Envirogard™ Quantitube® system uses a photometer that determines the concentrations of the chemicals in the samples within each kit's detection range. The detection range for triazine is 0.05 µg/l - 2.0 µg/l; alachlor is 0.1 µg/l - 5.0 µg/l.; and 2,4-D is 2.0 µg/l -100 µg/l. The photometer calculates an estimate of concentrations falling outside the detection range.

The tests for triazine, alachlor, and 2,4-D were able to detect other closely related compounds although the test was not able to differentiate between the main reactant and the other compounds. Those other compounds for the triazine test were atrazine,

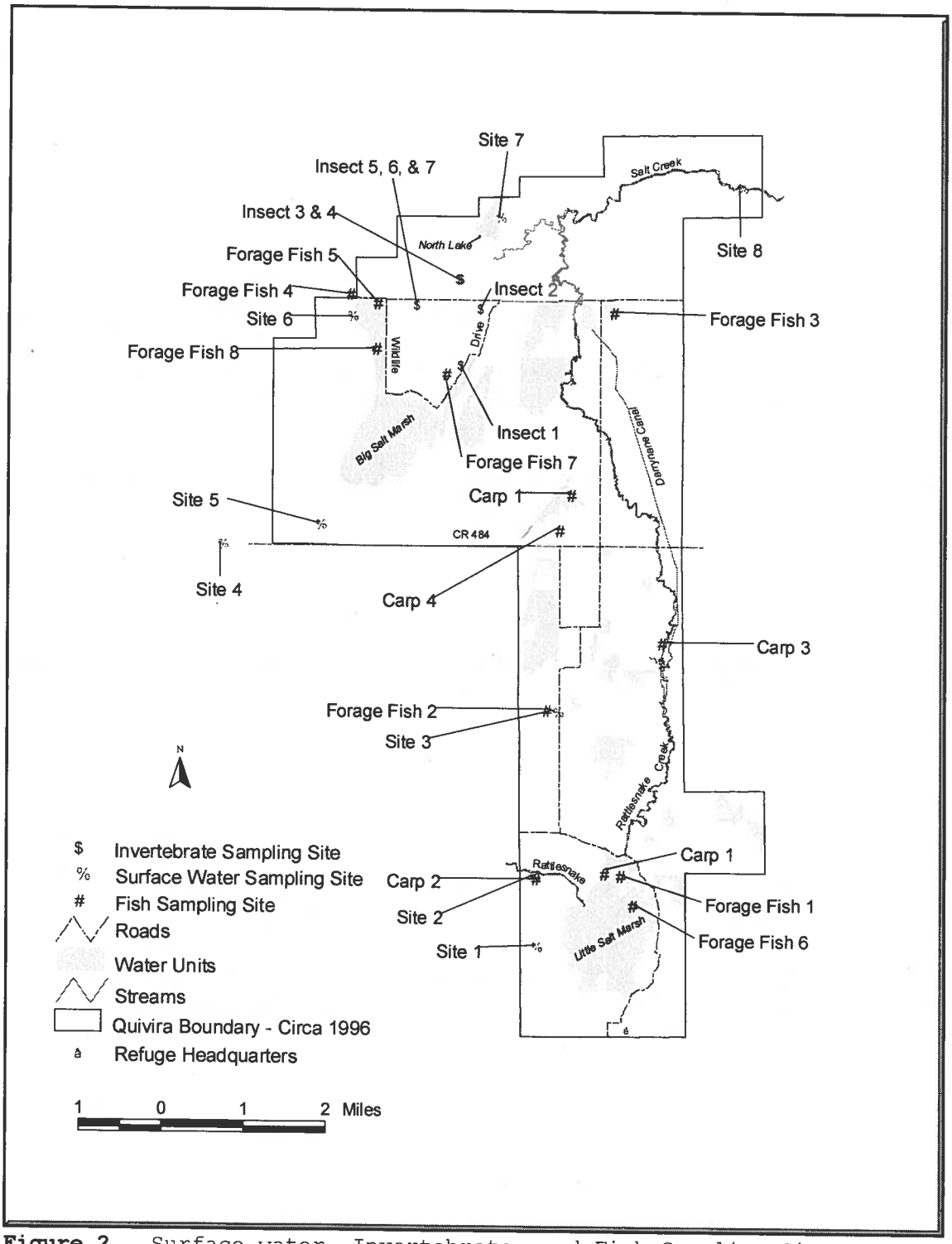

Figure 2. Surface water, Invertebrate, and Fish Sampling Sites

simazine, cyanazine, simetryn, prometryn, ametryn, propazine, trietazine, prometon, terbuthylazine, de-ethylated atrazine, di-dealkylated atrazine, diazinon, and 6-Hydroxy atrazine. The other compounds for the alachlor test were metolachlor, metalaxyl, and atrazine. For 2,4-D the other compounds were 2,4-D methyl ester, 2,4-D isopropyl ester, dichlorprop, MCPA, 2,4,5-T, and 2,4,5-TP.

We also collected surface water using the same water collection procedures at the same eight locations in June, July, and August 1997 for trace element analysis including selenium. Samples were held less than four hours before being filtered and preserved. Water samples were filtered at the field lab using a Geofilter® positive-pressure apparatus (Geotech, Denver, CO) through a 142mm (diameter) 0.45 micron polycarbonate filter and into 125 ml pre-cleaned, pre-acidified HDPE bottles provided by the United States Geological Survey (USGS), National Biological Service, Environmental and Contaminants Research Center (ECRC), Colombia, Missouri. The samples were then kept at room temperature until they were shipped to ECRC for analysis.

A Global Positioning System (GPS) unit was used to record the geographic coordinates of all sample locations. Maps depicting the hydrology of Quivira were generated using USFWS digital National Wetland Inventory (NWI) maps. Some of the waterbodies sampled were not represented in this source material and therefore, are not depicted on the maps included in this report. However, descriptions of all the water collection sites are provided as follows:

Site 1 - This small unnamed tributary enters Quivira on the west boundary south of Rattlesnake Creek and flows into the Little Salt Marsh. It is intermittent with pools of water remaining throughout the summer in most years.

Site 2 (Rattlesnake Creek) - The sampling site was located near Quivira's west boundary. Rattlesnake Creek is a perennial stream and flows into the Little Salt Marsh.

Site 3 (Windmill pond) - This is a small man-made pond with no inlet or outlet. A windmill located near the edge of the pond brings groundwater to the surface. This water flows into a stock tank which overflows into the pond. The water was collected as it flowed into the stock tank.

Site 4 - This small unnamed tributary flows into Big Salt Marsh. The sampling site was located outside of Quivira's boundary at a small pool near the road.

Site 5 (Pop Bead Pond) - This site is one of the larger pools of a series of small man-

made depressions south of Big Salt Marsh. They were built by Quivira staff and are collectively referred to by the staff as the Pop Bead Ponds. During most years, this pond holds water all year. It is fed by surface runoff and probably groundwater.

Site 6 - This is a roadside ditch on the north side of Big Salt Marsh and is connected to Big Salt Marsh.

Site 7 (North Lake) - The sampling site was on the north side of the lake. This waterbody receives sheet flow from off-refuge lands.

Site 8 - Salt Creek exits on Quivira's east boundary and is perennial. The sampling site was located at the area where the creek leaves Quivira.

Soil

We collected twenty-three soil samples from the vicinity of the oil production facilities (Figure 3). Generally, each sample represented an individual oil well or oil storage tank

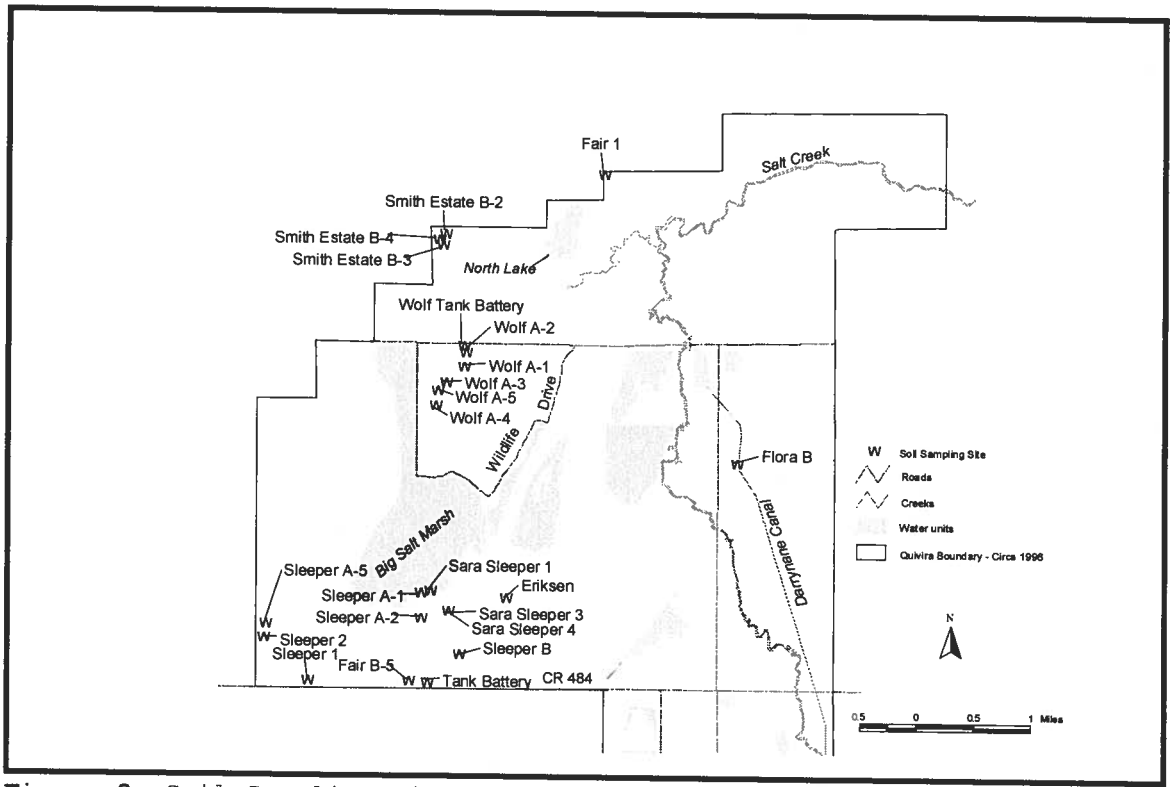

Figure 3. Soil Sampling Sites

battery area. However, the Sara Sleeper 3 well shares a berm area with the Sara Sleeper 4 well, so only one sample was taken for the combined well area. The sample names correspond to the oil well names used by the staff at Quivira. We collected from inside the berm area and from areas outside the berm that oil would most likely seep to if it spilled from the facilities. Personnel from Quivira assisted in these collections. Each sample was a composite from three or more areas representative of conditions near each oil production facility at each site. We sampled the soil at a variety of depths ranging from the surface to approximately 9 inches below the surface using a stainless steel spoon. The composited sample was mixed thoroughly and placed into a pre-cleaned 500 ml jar with a teflon lined lid. Soils samples were kept on ice until we returned to the office where they were frozen. The samples were submitted to contract laboratories for aliphatic and aromatic hydrocarbons, organochlorines, and trace elements analysis.

Invertebrates

We collected seven samples of insects from two large areas where we had observed least terns and other shorebirds feeding (Figure 2), a mudflat north of and across the road from the Big Salt Marsh and land around the northeast side of the Wildlife Loop road. We used a variety of methods to collect the insects including insect nets, deadfall traps, and hand collection. The insects from each of the seven sites were composited into precleaned glass jars with teflon lined lids. The samples included grasshoppers, beetles, flies, caterpillars, and crickets, etc. They were placed on ice or refrigerated until we returned to the office where they were frozen. The invertebrate samples were submitted to a laboratory for trace element and organochlorine analysis.

Fish

Fish were collected from 12 locations representing the flow of water into and through Quivira, and some of the impoundments and wetlands (Figure 2). We collected five samples of common carp (*Cyprinus carpio*) and eight samples of forage fish, the species of which we did not identify. Fish were collected with seines or with metal or plastic minnow traps. The forage fish were composited from each sampling site into a pre-cleaned glass jar with a teflon lined lid. The carp samples were composited and wrapped in aluminum foil and placed in a plastic bag. The fish samples were kept on ice until we froze them at our office. These samples were submitted to a laboratory for trace element, organochlorine, and petroleum compound analysis.

Laboratory Procedures

Two laboratories under contract with the Service's Patuxent Analytical Control Facility (PACF) were used to perform the sample analysis. Environmental and Contaminants Research Center (ECRC) conducted the analysis for selenium in water; particle size and percent organic carbon for soils; and trace elements in fish, insects, and soils. Geochemical and Environmental Research Group (GERG) at College Station, Texas performed the analysis for aliphatic and aromatic hydrocarbons and organochlorine on the soil, fish and invertebrate samples.

ECRC ECRC (1998) used the following sample preparation and analysis methods. Water samples were subjected to a combination nitric acid wet digestion and magnesium nitrate dry ashing (SOP C5.25) in preparation for the determination of selenium by hydride generation. Fish, invertebrate, and soil samples were subjected to a similar procedure (SOP C5.26) in preparation for the determination of arsenic and selenium by hydride generation. For the determination of elements by semi-quantitative scan and mercury by cold vapor hydride generation, biota and soil samples were subjected to a low-heat, low pressure acid oxidation with nitric acid, hydrochloric acid, and hydrogen peroxide (SOP C5.94). This procedure was conducted in a CEM microwave oven using sealed Teflon vessels. A portion of the diluted digestate was stored in a glass tube for mercury determination, and another portion was subjected to a microwave evaporative digestion to remove Cl^- prior to semi-quantitative analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (SOP C5.217). ICP-MS provides a high quality multi-element and isotopic analysis package with low detection limits. The detection limit for most elements is in the sub parts per billion range while for some elements it may lie in the sub parts per trillion.

The determination of selenium in water and selenium and arsenic in biota and soil was accomplished by flow injection hydride generation atomic spectroscopy (SOPs C5.157 and C5.172). Mercury in biota and soil was determined by flow injection cold vapor atomic spectroscopy (SOP C5.157). Semi-quantitative elemental scans of biota and soil were conducted using ICP-MS technology (SOP C5.212). The accuracy of the semi-quantitative scan is ±30% to ±50%, depending on the element.

GERG - Tissue Organics The following laboratory procedures were reported by GERG (1999). The tissue samples were homogenized with a Teckmar Tissumizer. A 1 to 10-gram sample (wet weight) was extracted with the Teckmar Tissumizer by adding surrogate standards, Na_2SO_4, and methylene chloride in a centrifuge tube. The tissue extracts were purified by silica/alumina column chromatography to isolate the aliphatic

and polyaromatic hydrocarbon (PAH)/pesticide/PCB fractions. The PAH/pesticide/PCB fraction was further purified by HPLC in order to remove interfering lipids.

The quantitative analyses were performed by capillary gas chromatography (CGC) with a flame ionization detector for aliphatic hydrocarbons, CGC with electron capture detector for pesticides and PCB's, and a mass spectrometer detector in the selected ion monitoring mode (SIM) mode for aromatic hydrocarbons. The SIM mode allows for a specific compound to be traced.

GERG - Soil Organics and Pesticides The following laboratory procedures were reported by GERG (1999). The soil samples were freeze-dried and extracted in a Soxhlet extraction apparatus. The freeze-dried soil samples were homogenized and a 10-gram sample was weighed into an extraction thimble. Surrogate standards and methylene chloride were added and the samples extracted for 12 hours. The extracts were treated with copper to remove sulfur and were purified by silica/ alumina column chromatography to isolate the aliphatic and aromatic hydrocarbons/ pesticide/PCB fractions.

The quantitative analyses were performed by capillary gas chromatography (CGC) with a flame ionization detector for aliphatic hydrocarbons, CGC with electron capture detector for pesticides and PCB's, and a mass spectrometer detector in the SIM mode for aromatic hydrocarbons.

There are specific cases where analytes requested for the pesticide and PCB analyses and are known to co-elute with other analytes in the normal CGC with electron capture. These include the pesticide Endosulfan I and PCB congeners 114 and 157. In these cases, the samples were analyzed by CGC with a mass spectrometer detector in the SIM mode.

RESULTS AND DISCUSSION

Herbicides in Surface Water

Triazine Thirty-three out of 56 samples (59%) analyzed contained a detectable concentration of triazine compounds (Table 1). The highest number (7 out of 8) of samples with detectable concentrations of triazine were collected in May, with the sample collected at Site 2 (Rattlesnake Creek entering Quivira) registering above the maximum detection level of 2.0 µg/l. Samples collected in September had the lowest number of

detections (2 out of 8). Site 2 and Site 8, Salt Creek exiting Quivira, had the highest concentrations found each sampling period.

Atrazine, a triazine compound, is the most frequently detected pesticide in Kansas surface water (Carney et al. 1991). Atrazine concentrations of 0.29 µg/l can inhibit photosynthesis of sago pondweed (*Potamogeton pectinatus*) by 50% under laboratory conditions (Fleming et al. 1995). Concentrations between 1 and 5 µg/l adversely affect phytoplankton growth and succession, which in turn can adversely affect higher levels of the food chain (Eisler 1989). Aquatic fauna are indirectly impacted through the reduction of the food supply of herbivores and loss of macrophyte habitat (Eisler 1989). Recent work on the effects of atrazine on amphibians has found that concentrations less than 0.1 µg/l produced gonadal abnormalities in African clawed frogs (*Xenopus laevis*) (Hayes et al. 2002). Of the 56 samples collected, nineteen samples had concentrations equal to or greater than 0.1 µg/l, eight had concentrations equal to or greater than 0.29 µg/l, and two had concentrations equal to or greater than 1.0 µg/l. Fourteen of the samples with concentrations exceeding 0.1 µg/l were taken from April through July which coincides with critical developmental stages for frogs. Four of the samples with concentrations exceeding 0.29 µg/l were taken in May, one sample each in June and July, and two samples in August.

2,4-D None of the 56 total samples analyzed contained more than the detectable concentration of 2.0 µg/l (Table 2) although the photometer estimated concentrations below the detection range for all the samples.

Although information on sublethal effects of low concentrations of 2,4-D is limited, research has indicated that concentrations >10 µg/l inhibits photosynthesis in sago pondweed by 50% in laboratory experiments (Fleming et al. 1995).

Alachlor Six of the 56 water samples (11%) analyzed contained concentrations equal to or greater than the 0.1 µg/l minimum detection level for alachlor (Table 3). The six samples came from Site 2 (Rattlesnake Creek entering Quivira) and Site 8 (Salt Creek exiting Quivira) in the months of May, June and August. Site 2 in May had the highest concentration found at 3.11 µg/l.

Alachlor is water soluble and can readily move to groundwater, especially in sandy soils. In vegetation it is absorbed primarily by germinating shoots and it is readily translocated throughout the plant. Higher concentrations appear in the vegetative parts than in the reproductive parts of the plant. Alachlor is rapidly metabolized to water-soluble products in plants.

Conclusion Concentrations of all three chemicals or their transformation products were either detected or extrapolated by the photometer in surface waters from April through October. Although low concentrations of these chemicals may not cause direct mortality to aquatic organisms, they can negatively impact aquatic ecosystems through changes in species composition and community structure (Eisler 1989) or by reducing vigor in some species by inhibiting photosynthesis (Fleming et al. 1995). Such effects for atrazine have been well demonstrated in aquatic systems (deNoyelles et al. 1982, Dewey 1986, Eisler 1989, Hoagland et al. 1993, Jüttner et al. 1995, Kosinski and Merkle 1984, Pratt et al. 1988, Stay et al. 1989, and Stratton 1984).

Triazine compounds, including atrazine, could be a serious concern for Quivira due to the frequency of detection of triazines and the potential for effects, at low concentrations, to amphibians. However, more detailed work would be needed to evaluate this situation. No conclusive statement can be made at this time.

Also of concern are the interactive, cumulative, and synergistic effects of combinations of these chemicals and their transformation products on aquatic ecosystems. Larson et al. (1997) surmised that the interactive effects of pesticides, their transformation products, and any other chemicals could lead to situations where degradation products of low individual toxicity still pose a serious threat to non-target organisms when in combination. Though pesticide transport to surface waters depends on external factors such as rainfall, pesticide solubilities, and the persistence of the pesticides (Wauchope 1978), improved land and crop management practices can reduce pesticide mobilization. For example, recent efforts in northeastern Kansas have shown that atrazine levels in surface waters can be reduced with better application and land management practices. These efforts can lead to a reduction in the typical late spring/summer peak in atrazine levels (Spiegel 1996).

Our sampling indicates that compounds of the herbicides 2,4-D, alachlor and triazines are entering Quivira through the surface water in Rattlesnake Creek. In addition, concentrations of some of the herbicides increased where Salt Creek exits Quivira. None of these pesticides are used on Quivira, therefore the influx of herbicides at this location is likely due to runoff from agricultural land in close proximity north of this site or it is possible that groundwater is transporting contaminants into the creek near this site. A more detailed study of herbicide fate and effect may by warranted in the future.

Selenium in Surface Water

Selenium concentrations in water are presented in Table 4. The selenium concentrations from Site 3 were 3.25 µg/l, 3.3 µg/l, and 2.7 µg/l for the months of June, July and August, respectively. The source of water at this site is groundwater brought to the surface by a windmill. The water flows into a stock tank and then overflows into a manmade pond with no outlet. This was the only site where we directly sampled groundwater pumped to the surface. These concentrations are greater than the 2 µg/l considered potentially hazardous to the health and long-term survival of fish and sensitive species of birds from food-chain bioaccumulation by Lemly (1993). All the other sites had concentrations ranging from <0.32 to 1.6 µg/l. In comparison, normal background concentrations of selenium in freshwater ecosystems negligibly influenced by agricultural or industrial mobilization of selenium were estimated at 0.1 µg/l to 0.25 µg/l (Skorupa et al. 1996). A survey of inland saline lakes in the western United States yielded a geometric mean of 0.6 µg/l (Skorupa et al. 1996). Low concentrations of selenium in water can be bioaccumulated to toxic levels in fish and wildlife via dietary exposure to the aquatic food chain; selenium poisoning in fish and birds has been documented for waters averaging 1.5-10 µg/l of selenium (Skorupa et al. 1996).

Trace Elements in Soils and Biota

Because of the potential for toxicological effects, we were primarily interested in selenium, arsenic, mercury, copper and lead concentrations in the soils (Table 5), invertebrates (Table 6), and fish (Table 7) of Quivira. However, the standard analytical methodology includes the analysis of 58 additional trace elements. We have included these results as a reference of conditions in 1996 (Soils, Table 8; Invertebrates, Table 9; and Fish, Table 10). Toxicity of metals in soil and invertebrates is difficult to establish because factors, including soil properties such as organic mater content and pH, species of invertebrate, and age of individuals, will greatly influence the bioavailability of the metals and therefore their toxicity.

Selenium Selenium concentrations in fish from Quivira averaged 2.07 µg/g and ranged from 0.9 µg/g to 3.7 µg/g dry weight. For comparison, selenium concentrations in fish at selenium contaminated sites in the United States range from 4.28 µg/g to 197 µg/g dry weight (Sorensen 1991). Three samples, Forage Fish 2 (3.5 µg/g), Forage Fish 4 (3.7 µg/g) and Forage Fish 6 (3.2 µg/g), had concentrations approaching the biological effects threshold of 4 µg/g dry weight for the health and reproductive success of freshwater fish (Lemly 1993). The sample "Forage Fish 2" was from the pond at water

sample Site 3, which contained elevated concentrations of selenium.

Concentrations of selenium in invertebrates ranged from 0.15 µg/g to 1.1 µg/g dry weight, well within the background selenium concentration for terrestrial invertebrates of <0.1 to 2.5 µg/g dry weight reported by Skorupa et al. (1996). No invertebrate samples were taken from water sample Site 3.

Selenium concentrations in soils taken from the oil production facilities ranged from <0.03 µg/g to 0.71 µg/g dry weight. The geometric mean of selenium in soils for the western U.S. (west of the 96th Meridian) is 0.23 with a range from less than 0.1 to 4.3 µg/g dry weight (Shacklitte and Boenger 1984). Selenium readily enters the metabolic pathways of plants and animals and is highly bioaccumulative (Skorupa et al. 1996). Because soils, insects, fish and water were not sampled at the same sampling sites it is difficult to draw conclusions about selenium in the food chain of Quivira. Although concentrations of selenium increased from soil to invertebrates to fish the concentrations where generally low which suggest that selenium is not appreciably accumulating into the food chain.

Arsenic Arsenic in biota ranged from 0.10 µg/g to 1.5 µg/g and averaged 0.54 µg/g dry weight. Arsenic concentrations in fish ranged from 0.25 to 1.5 µg/g and averaged 0.60 µg/g. This average is below the nationwide 85th percentile value of 0.92 µg/g dry weight for 1978-1979 and 0.88 µg/g dry weight for 1980 - 1981 for whole body fish (Lowe et al. 1985). Forage Fish 8 had an arsenic concentration (1.5 µg/g) nearly double that found in any other sample, but we do not believe arsenic concentrations in fish from the refuge are of concern.

Arsenic in the soil samples averaged 2.1 µg/g dry weight and ranged from 0.52 to 5.6 µg/g dry weight. Arsenic in soils of the U.S. ranges from <0.1 µg/g to 93 µg/g dry weight (Kabata-Pendias and Pendias 1991). The geometric mean for U.S. surficial materials is 5.8 µg/g (Kabata-Pendias and Pendias 1991). The lowest arsenic levels are found in sandy soils while higher arsenic concentrations are most often found in alluvial soils and soils rich in organic matter (Kabata-Pendias and Pendias 1991). Therefore, since Quivira has predominantly sandy soils, we would expect low arsenic concentrations in soil on the refuge. We do not believe that arsenic concentrations in soil or biota from the refuge are of concern.

Mercury Mercury in the invertebrate samples ranged from 0.028 µg/g to 0.14 µg/g dry weight. Forage fish and carp contained mercury concentrations ranging from 0.096 µg/g to 0.31 µg/g dry weight. Eisler (1987a) recommends a maximum of 0.1 µg/g wet weight

in food items to protect birds.

All of the soil samples from Quivira contained concentrations of mercury <0.085 µg/g dry weight. Mean background concentrations of mercury in surficial materials of the United States is 0.065 µg/g dry weight (US Dept. of Interior 1998). In general, organic soils have higher mercury levels than mineral soils (Kabata-Pendias and Pendias 1991). Although background levels of mercury in soils are difficult to estimate due to widespread mercury pollution, unpolluted soils have an estimated range of 50 µg/kg to 300 µg/kg dry weight of mercury (Kabata-Pendias and Pendias 1991). Thus mercury pollution in soils and biota on the refuge is not a concern at this time.

Copper Copper concentrations in the fish samples were low ranging from 2.0 to 7.0 µg/g dry weight with the exception of Forage Fish 8. This sample, from the north end of the Big Salt Marsh, had a copper concentration of 10 µg/g dry weight. The level of concern for whole body fish is 9.8 µg/g dry weight (US Dept. of Interior 1998). At this concentration a slight increase in mortality was observed in rainbow trout (*Oncorhynchus mykiss*) (US Dept. of Interior 1998).

Although a level of concern has not been established for invertebrates (US Dept. of Interior 1998), we do not believe that copper in terrestrial invertebrates collected from Quivira is a cause for concern at this time. The collected samples fall within the expected ranges. Copper has been identified as an essential trace element for terrestrial invertebrates (Hopkin 1989). Roth (1992) states that concentrations of copper in most insects varies between 20 and 40 µg/g. Other studies have found that copper concentrations ranging from 25 µg/g to 2608 µg/g dry weight caused no observable effect in terrestrial invertebrates (van Straalen 1993). Concentrations of copper in the invertebrate samples collected for this study ranged from 10 µg/g to 40 µg/g dry weight.

Background copper concentrations in soil range from 13 µg/g to 24 µg/g dry weight in uncontaminated areas (US Dept. of Interior 1998). Concentrations in the soil samples from Quivira ranged from 2 µg/g to10 µg/g dry weight. Thus, copper concentrations in soils on the refuge is not a concern at this time.

Lead Lead is a cumulative, metabolic poison which is neither beneficial or essential to living organisms. Eisler (1988) states that lead is toxic in most of its chemical forms and that "all existing data show that its metabolic effects are adverse". The toxicity of lead varies widely among species and is caused by many factors including life stage, water quality, and the presence of other elements (Sorensen 1991). Early studies suggest that 0.1 - 10 µg/g dry weight of lead represents toxic levels for several species.

Lead concentrations in the soil samples ranged from 2 to 40 µg/g dry weight. The natural lead occurrence in the top horizons of different soils from various countries range from 3 to 189 µg/g dry weight and average 32 µg/g dry weight (Kabata-Pendias and Pendias 1991). A suggested upper limit for the lead content in a normal soil is 70 µg/g dry weight (Kabata-Pendias and Pendias 1991).

The terrestrial invertebrate samples contained lead concentrations less than or equal to 1.0 µg/g dry weight. Terrestrial invertebrates collected in a spruce forest in central Europe which was characterized as relatively uncontaminated with metal pollutants except for lead, had lead concentrations ranging from 0.3 to 76.0 µg/g (Roth 1992).

Lead concentrations in whole body fish collected for this investigation were less than 1 µg/g dry weight with the exception of sample "Forage Fish 8", collected from the north end of the Big Salt Marsh, which had a lead concentration of 2 µg/g dry weight. For comparison, fish samples collected at Flint Hills National Wildlife Refuge (Allen 1991a), Kirwin National Wildlife Refuge (Allen 1991b) and in the Republican River drainage (Allen and Fannin 1993) had no detectable concentrations of lead. Fish collected in the Spring River Basin (Allen and Wilson 1992), which drains the zinc mining area of southeast Kansas, had lead concentrations ranging from not detected to 7.3 µg/g dry weight. The highest reported concentration for lead in fish samples collected from the Mississippi River Basin for the 1995 National Contaminant Biomonitoring Program (Schmitt 2002) was 0.69 µg/g wet weight.

Our sampling indicates that lead contamination is not widespread on the refuge but there may be localized areas of possible lead contamination. Although lead might reach the refuge through aerial deposition, more likely sources of lead on the refuge would be lead shot, lead fishing sinkers, and gasoline emissions containing lead. Areas subject to lead contamination would presumably be those areas heavily hunted or fished, or located next to heavily traveled roads. The Big Salt Marsh, sampling site for Forage Fish 8, is located near a main road through the refuge as well as the wildlife drive, and fishing and hunting activity occurs in the area. As the use of lead shot is now prohibited for use on the refuge and lead is no longer an additive in gasoline, we would expect the concentrations of lead to decrease over time under normal circumstances. However, due to the elevated lead concentration in the forage fish sample, future studies might focus on the extent and sources of lead in biota particularly in the area around the Big Salt Marsh.

Organic Carbon and Grain Size Composition of Soil Samples

The majority of soil samples from Quivira were generally classified as sandy clay loam, with a high proportion of sand, and a low organic carbon content (Table 11). Non-polar organic contaminants such as PCBs and polycyclic aromatic hydrocarbons (PAHs) are adsorbed more strongly to finer grain particles, and are therefore less available to biota (Colombo et al. 1989). Soils low in organic carbon have less adsorptive capacity, thus contaminants like petroleum hydrocarbons may be more available to biota (Neff 1984). Although soils low in organic carbon tend not to be the sink that highly organic soils are when the contaminants are there (from a spill for example) they pose a greater risk.

Aliphatic Hydrocarbons in Soil and Fish

Although wildlife and fish are commonly exposed to petroleum compounds, assessments of petroleum hydrocarbon concentrations in, and their effects on, fish and wildlife are difficult to make (Hall and Coon 1988). Both biogenic (plant derived) and petrogenic (petroleum derived) aliphatic hydrocarbons (AH) can be found in the environment. Differentiating between the two is important in the interpretation of hydrocarbon residues in soil and biota. Several indices have been found useful to discern the sources of AHs (Colombo et al. 1989).

In general, petroleum-derived hydrocarbons are indicated by the presence of phytane and a series of odd and even number carbon aliphatics. In un-oiled matrices, phytane concentrations are usually less than 0.001 µg/g dry weight. Petrogenic compounds have approximately a one to one ratio (1:1) of total odd-carbon alkanes and even-carbon alkanes (Codd/Ceven) (Tran et al. 1997). Concentrations of pristane and phytane (Pri/Phy) are nearly equal in petroleum contaminated samples (Gearing et al. 1976, Keizer et al. 1978). Another index is the ratio of the sum of n-alkanes $\leq$20 divided by the sum of n-alkanes $\geq$21(Colombo et al. 1989), expressed as the low molecular weight/high molecular weight (LWM/HWM) ratio. Crude oil, plankton, and algae usually have a value close to 1.0 while sedimentary bacteria, marine animals, higher plants and sediments show lower values for this ratio. The C16 ratio, which is the sum of all the n-alkanes/n-C16, is usually high (i.e. 50) for biogenic materials compared to relatively low values (i.e. 15) in oily samples (Colombo et al. 1989). The presence of unresolved complex mixture (UCM) is indicative of petrogenic sources of AHs. It is composed of cyclic and branched alkanes. UCM resists microbial degradation more effectively than n-alkanes and thus has a greater tendency to remain in the environment after n-alkanes have degraded (Lee 1976, Lytle et al. 1979). Although UCM alone may not be sufficient

in confirming the presence of petroleum products additional evidence such as the presence of pristane and phytane with relatively low values of C17/Pristane (C17/Pri) and C18/Phytane (C18/Phy) (<3) indicate at least partial petrogenic contamination (Keizer et al. 1978). Low C17/Pri and C18/Phy ratios indicate the presence of degraded oil (Colombo et al. 1989). The carbon preference index (CPI) is calculated by the formula 2(C27 + C29)/(C26 + 2C28 + C30). A CPI value less than 3 indicates contamination by petrogenic sources (Farrington and Tripp 1977).

Aliphatic hydrocarbons in soil. Most of the AHs were found in all of the soil samples (Table 12). Several samples did not contain detectable levels of n-C10 through n-C15 and n-decane (–C10) was only found in one sample. All but two samples contained UCMs. Only the samples taken from Flora B and Sleeper A-5 did not contain detectable concentrations of phytane and pristane. While the results of the indices (Table 13) do not conclusively identify the predominant source of the hydrocarbons in most of the soil samples some conclusions can still be made. The AHs in the samples from Sleeper A-5 and Flora B are most likely from biogenic sources. Although both samples contained a UCM component, it was less than 100 µg/g wet weight. The Sleeper A-5 sample did not meet the criteria of any of the indices indicating petrogenic sources while Flora B met the criteria for only one index. The rest of the soil samples met the criteria indicating petrogenic sources of AHs from two or more of the indices used. Of those samples, two locations, Wolf A-2 and Wolf A-4 met the criteria for all the indices. While it is probable that all of the samples except Sleeper A-5 and Flora B have petrogenic sources of AHs, it is almost certain that the soils around the Wolf A-2 and Wolf A-4 pumps have experienced contamination associated with petrogenic sources. Allen (1991c) suspected petrogenic contamination near the Wolf A series of pumps, and this investigation corroborates his initial conclusions.

Given that all the samples were collected in the immediate area of the oil production wells and storage tanks, it is not too surprising that the indices indicate that most of the soils contain petrogenic AHs. In addition to the production of oil, most of the pumps use petroleum products for operation. Concerns arise due to the presence of the wells and storage tanks near aquatic and wetland areas and the high groundwater level present on Quivira. Any spills or leaks from the oil production facilities could seep into the groundwater and surrounding areas due to the sandy, highly permeable soils and the high water table.

Aliphatic Hydrocarbons in Fish. Oil contamination effects on adult fish are usually subtle and long term. Feeding, migration, reproduction, swimming activity, or schooling

behavior may be altered in response to sublethal concentrations of petroleum hydrocarbons. Early life stages are much more sensitive and usually experience higher mortality which can translate into long-term reduction in population abundances (Kennish 1997).

The sample from the Forage Fish 8 site, from the north end of the Big Salt Marsh, was not analyzed for AHs because of insufficient tissue for analysis. Concentrations of aliphatics in many of the fish samples (Table 14) were higher than those in soils. However, the results of the indices (Table 15) are more inconclusive as to the source of the aliphatic hydrocarbons than were those for the soils and we find it difficult to ascertain the source of AHs for individual samples using these indexes.

Several indices indicated that a preponderance of the aliphatic hydrocarbons are from biogenic sources. The pristane concentrations were low. The C17/Pri ratios were high. The Pri/Phy ratios were not close to unity. All the samples had LWM/HWM values lower than 1.0.

Other indices indicate that the source of the aliphatic hydrocarbons in the fish samples is petrogenic in origin. All fish samples contained unresolved complex mixtures although the values were low for many of the samples. The CPI values for all the fish samples were close to 1. The ratios of Codd/Ceven were close to unity. The C18/Phy ratios were low. For the majority of samples, the C16 Ratio was less than 50 with most of the samples falling in the 20 - 30 range.

Polycyclic Aromatic Hydrocarbons in Soil

PAHs are high molecular weight compounds with low solubility in water that are readily adsorbed on sediments. They are fairly reactive and are subject to oxidation and photolysis. Waste products associated with industries and municipalities, such as incomplete combustion of organic mater from internal combustion engines, power generation plants, incinerators, etc. (U.S. Public Health Service 1990), can travel great distances to contribute to soil PAHs in isolated areas through atmospheric deposition (Edwards 1983). Major sources of PAHs in the environment include petroleum spills, oil seepage, and runoff from roads (Hellou 1996, Kennish 1997). However, low concentrations of PAHs in the terrestrial environment have always been present as a result of synthesis in terrestrial vegetation, microbial synthesis, volcanic activity, and prairie and forest fires (Hellou 1996, Kennish 1997). PAHs are so omnipresent in the environment that it is now almost impossible for living resources to avoid exposure to

large quantities of these substances (Eisler 1987b). PAHs have been detected in animal and plant tissues, soils, sediments, air, surface water, drinking water, industrial effluents, ambient river water, well water, and groundwater (Eisler 1987b). The presence of alkylated naphthalene, phenanthrenes, and dibenzothiophenes in samples indicates petrogenic hydrocarbons (Neff 1985). Concerns about PAHs in the environment arise because they are persistent and some of them are potent mammalian carcinogens (Eisler 1987b). However, in general, PAHs tend to be associated with chronic impacts rather than acute. These impacts are often the result of exposure to low levels of complex mixtures of PAHs rather than exposure to just one compound (Irwin et al. 1998). Chronic exposure to low concentrations of PAHs in water, sediments, or food may cause changes in the behavior patterns of aquatic organisms (Neff 1979). These effects may be more evident at different life stages in different organisms (Kennish 1997).

PAHs are ubiquitous in soil and can readily enter the food chain. In the soil PAHs may be assimilated by plants where they can accumulate, degraded by soil microoganisms, or accumulated to relatively high levels in the soil (Eisler 1987b). In plants they may translocate into the stem, shoots and leaves. PAHs accumulated in plants grown in contaminated soils and researchers theorize that this also occurs in sediments and aquatic plants. Metabolic degradation of PAHs by soil and sediment microbes can transform PAHs into more hazardous chemicals (Irwin 1998). PAHs find their way into aquatic environments through deposition and from PAH contaminated runoff (Neff 1985). Permeable sandy soils combined with a high water table and the potential for flooding increases the risk of groundwater and surface water contamination (Barbash and Resek 1996). These conditions are present on the refuge. Once in the water column PAHs become incorporated into bottom sediments and may concentrate in aquatic biota or experience chemical oxidation and biodegradation (Eisler 1987b). Research is needed to establish the soil PAH levels above which PAH constituents adversely affect the food chain (Eisler 1987b).

Local sources of PAHs in Quivira's environment include prairie fires, vehicle traffic, exhaust from the oil well pump engines, and releases from the oil wells. However, since PAHs in the atmosphere can travel great distances, pathways to Quivira could include distant sources.

Each PAH included in the analysis was found in at least one sample, but most were detected in fewer than 50% of the samples (Table 16). Only naphthalene was detected in every sample and C-1 naphthalene was detected in all but two samples. Other PAHs detected in greater than or equal to 50% of the samples include 1-methylphenanthrene (57%), 2-methylnaphthalene (65%), benzo(g,h,i)perylene (52%), C2-naphthalene (74%),

C3-naphthalene (65%), C4-naphthalene (57%), chrysene (74%), fluoranthene (65%), and phenanthrene (61%). Benzo(e)pyrene, C1-phenanthrene & anthracenes, C2-phenanthrene & anthracenes, and pyrene were detected in 48% of the samples. Benzo(a)pyrene, identified as one of the most carcinogenic PAHs (Eisler 1987b), was detected in 30% of the samples. Because this study only collected data on PAHs in soils, the effect of PAHs on the refuge habitats and wildlife is unknown. A more detailed study would be needed to evaluate the potential for biological effects from petroleum hydrocarbons, PAHs in particular.

Organochlorines in Soil, Invertebrates, and Fish

Most of the organochlorines (OCs) were either not detected in the soil samples or were found in only a few of the soil samples, with the exception of total PCBs which were found in all but one of the soil samples (Table 17). In 1972 the National Academy of Sciences and National Academy of Engineers established the following criteria for the protection of fish-eating wildlife: DDT and its metabolites, 1.0 μg/g dry weight (total); dieldrin, aldrin, endrin, BHC, heptachlor epoxide, chlordane, and toxaphene, 0.1 μg/g dry weight either singly or in combination; and PCB's 0.5 μg/g dry weight (total) (Schmitt et al. 1983). None of the soil samples from this study exceeded these criteria.

In addition, few organochlorine compounds were detected in the invertebrate samples (Table 18). The exceptions were endrin, total PCBs and the DDT compounds. Every sample contained PCBs. Total DDT was detected in all but one sample. Endrin was detected in five out of the seven samples.

Organochlorines concentrations in the fish samples are presented in Table 19. The OCs beta BHC, gamma chlordane, o,p'-DDE, and o,p'-DDT were not detected in any of the fish samples. Most of the other OCs were detected in only a few of the samples. The exceptions are aldrin, alpha chlordane, delta BHC, dieldrin, HCB, heptachlor, p,p'-DDD, and p,p'-DDT. These compounds were found in at least 50% of the samples. Total PCB and p,p'-DDE (as well as total DDT) were found in every sample. Sufficiently high levels of PCB and DDT contamination can hinder fish adaptation to changes in salinity and may contribute to the decline in populations (Kennish 1992). At Quivira, one would expect to see seasonal changes in salinity occurring during periods of low precipitation, especially if groundwater is contributing significantly to the surface water, and/or when evaporation is high. PCB, DDT, aldrin, dieldrin, heptachlor, and chlordane have been removed from the market. Aldrin and heptachlor are rapidly metabolized to dieldrin and heptachlor epoxide, respectively (Schmitt 1990). However, heptachlor occurs as a minor

component of technical chlordane and Schmitt et al. (1985) recommends that heptachlor epoxide should be included when chlordane residues are discussed and evaluated.

Chlordane The concentrations of total chlorodane in fish collected for this study ranged from not detected to 0.0425 µg/g wet weight which were lower than the geometric mean concentrations of total chlordane (except methoxychlor) for fish collected from 1976 to 1984 for the National Contaminants Biomonitoring Program (NCBP). The NCBP geometric mean concentrations ranged from 0.12 µg/g to 0.20 µg/g dry weight (Schmitt et al. 1990). Concentrations of alpha chlordane in carp were similar to those found in carp collected from the Neosho River (Allen and Blackford 1995). In general, the carp collected during this investigation contained higher concentrations of chlordane than did the forage fish composites, some of which included juvenile carp.

PCB The use of PCBs has been restricted in the United States since 1979. However, they are slow to degrade and have been found in most environments throughout the world (Kennish 1992). PCBs are highly lipophilic and are known to biomagnify and bioaccumulate (Eisler 1986). The mean for total PCB concentrations in the 1984 NCBP was 0.39 µg/g wet weight (Schmitt et al. 1990). All fish samples collected for this study had concentrations of total PCBs less than or equal to 0.0777 µg/g wet weight. The proposed PCB criteria for the protection of various resources and human health is less than 0.4 µg/g for fresh weight whole body fish (Eisler 1986). Although PCBs are present in Quivira's fish, it does not appear that they are in concentrations that are detrimental to other resources.

DDT DDT and it's metabolites DDE and DDD are synthetic organochlorine compounds which have been used extensively for insect control throughout the world. These two persistent metabolites and DDT are often found together in the environment and are referred to collectively as total DDT (US Dept. of Interior 1998). While DDT has been banned in the United States since 1972, it is still used in many parts of the world and is transported into the US through animal migration and air movement. Concentrations of total DDT in the Quivira carp and forage fish samples ranged from 0.0009 to 0.0223 µg/g wet weight. Concentrations in fish collected for the 1984 NCBP had a geometric mean of 0.26 µg/g wet weight (Schmitt et al. 1990). The concentrations found in this study are low and not expected to be biologically significant.

Aldrin Aldrin is readily converted to dieldrin (Peakall 1996). Aldrin has not been sold for agricultural purposes since 1974 (Schmitt et al. 1990). The toxicity of the two compounds is about the same in most media except that in fish dieldrin is an order of magnitude more toxic than aldrin (Peakall 1996). One or both of the chemicals were

detected in all but one of the fish samples collected at Quivira (Forage Fish 4). Aldrin was detected in 9 out of 12 fish samples at concentrations <0.0064 µg/g wet weight. Dieldrin was detected in 8 of the 12 samples at concentrations ranging from 0.0004 to 0.0013 µg/g wet weight. These concentrations are lower than the geometric mean of 0.04 µg/g wet weight (Schmitt et al. 1990) for dieldrin concentrations for fish in the 1984 NCBP.

None of the invertebrate samples contained detectable concentrations of either chemical. One soil sample contained a detectable concentration of aldrin and seven (30%) soil samples contained detectable concentrations of dieldrin. The concentrations found in this study are low and not expected to be biologically significant.

Endrin Endrin was used as an insecticide on wheat crops. It is more toxic than either aldrin or dieldrin, and is more toxic to fish than to invertebrates (Johnson and Finley 1980). Endrin residues can accumulate rapidly in terrestrial and aquatic invertebrates (Van Esch and Van Heemstra-Lequin 1992). Residues of endrin were found in waterfowl that frequented treated areas in the Northern Great Plains after endrin was used to protect small grains from army cutworms (*Euxoa auxiliaris*) during 1981 (Schmitt et al. 1985). Fish exposed to endrin through food sources or the aquatic environment can accumulate concentrations of 400 to 2,000 times the exposure level (Johnson and Finley 1980). It can cause sublethal effects including altered growth and reproductive development and altered behavioral patterns (Johnson and Finley 1980). The major source of endrin in soil is from direct application to soil and crops (Van Esch and Van Heemstra-Lequin 1992). The most important pathway of endrin contamination of surface water is run-off from soil (Van Esch and Van Heemstra-Lequin 1992).

Fish sample Carp 2, from Rattlesnake Creek at the southwest corner of the Refuge, had a concentration of 0.0016 µg/g wet weight. Endrin was detected in five (71%) of the invertebrate samples at concentrations ranging from 0.0014 to 0.0046 µg/g wet weight. Endrin was detected in four soil samples (17%) at a concentration of 0.0001 µg/g wet weight. In a 1971 national soil monitoring program fourteen out of 1486 soil samples (0.9%) had detectable endrin at a geometric mean concentration of <0.001 mg/kg dry weight (Van Esch and Van Heemstra-Lequin 1992).

Heptachlor Heptachlor was used as a seed dressing for wheat, as a soil treatment for corn, and to control fire ants and termites. Most uses of heptachlor in the United States were phased out by 1983 (Wiemeyer 1996). Heptachlor is quickly metabolized to heptachlor epoxide in vertebrates. Both heptachlor and heptachlor epoxide have been shown in laboratory tests to disrupt the endocrine system of some organisms (Larson et al. 1997). It is interesting to note that in Quivira's fish samples heptachlor was found in

nine (75%) of the samples, while heptachlor epoxide was only found in two (17%) of the samples. However, the concentrations were below effect concentrations (Jarvinen and Ankley 1999). None of the soil samples contained detectable concentrations of heptachlor and heptachlor epoxide was detected in only one soil sample.

Summary

Although our sampling effort was not intensive, we attempted to identify possible sources through which contaminants might enter Quivira. We looked at surface water, soils, and prey food items for snowy plovers (terrestrial invertebrates) and least terns (fish).

Low waterborne concentrations of triazine, alachlor, and 2,4-D compounds were found in streams entering Quivira. In general, concentrations of these compounds seemed to be higher at sites located near the periphery of Quivira and decrease in the interior portions of the refuge. Triazine compounds were the most frequently detected pesticide in the surface water. Triazine compounds, including atrazine, could be a serious concern for Quivira due to the frequency of detection of triazines and the potential for effects, at low concentrations, to amphibians. However, more detailed work would be needed to evaluate this situation.

Data from this study supports the conclusion of a prior investigation (Allen 1991c) that at least some of the oil production facilities on Quivira are a source of PAHs. Two oil wells in particular appear to be releasing petrogenic aliphatic hydrocarbons into the soils. The permeable sandy soils combined with a high water table and the potential for flooding increases the risk of groundwater and surface water contamination. Future studies should determine if petroleum hydocarbon contamination is affecting the aquatic communities.

The results of this study indicates that selenium might have entered Quivira surface water from groundwater. The importance of groundwater contributions of contaminants to surface waters varies both geographically and seasonally. It can be important in areas where the groundwater is released to surface waters, as it is on Quivira. In rivers, the input of contaminants by groundwater is minimal or negative in periods of high flow, but is often significant and perhaps dominant in periods of low flow (Larson et al. 1997). The input may also be significant in areas where the contaminants may be concentrated due to evaporation such as a pond with no flow-thru. Future investigations should focus on groundwater to determine if significant contamination is entering Quivira through this source, and if so, determine the extent of contamination. Additional investigations should focus specifically on selenium to determine if selenium is causing localized problems

and/or if selenium in groundwater affects larger areas during low water conditions. Sampling locations should include the artesian wells located on Quivira, sites where ground water is pumped to the surface and then enters the surface water flow through Quivira, areas where groundwater naturally discharges to the surface waters, and waterbodies that do not have a flow-thru water supply.

Aldrin and heptachlor were detected in over 50% of the fish samples. Both were primarily used as soil treatments, but the terrestrial invertebrates did not contain detectable concentrations and only one soil sample contained a detectable concentration of aldrin. Hepatchlor expoxide was also detected in one soil sample. However, the concentrations detected were below levels of concern.

Endrin was detected at extremely low concentrations in the tissues of 71% of the terrestrial invertebrate samples and one fish sample. Endrin accumulates rapidly in fish and is highly toxic to them (Johnson and Finley 1980).

All of the carp and forage fish samples contained p,p'-DDE as did as five (71%) of the insect samples. Only seven (30%) of the soil samples contained detectable concentrations.

Most chlordane compounds in soils, insects, forage fish and carp collected for this investigation were not detected or were detected at very low levels and probably are not greatly impacting the food chain on the refuge.

Elevated copper, lead, and selenium concentrations were found in one forage fish. Selenium in water was found at a level of concern at one location. Areas where these samples were taken should be more extensively sampled to determine the extent and possible source of the elevated concentrations of these elements.

Management Actions

To assess the potential for pesticide impacts on Quivira's environments through surface water pathways, future studies could focus on intensive (hourly, daily, weekly) pesticide monitoring in Rattlesnake Creek and other surface water entering Quivira during the spring planting season when pesticide use is greatest. These data will provide the basis for a more accurate evaluation of agricultural management practices and information useful in modeling the transport and fate of agricultural chemicals. Potential impacts to Quivira's aquatic ecosystems caused by pesticides in run-off could be lessened by

diverting spring surface water flows from Quivira after precipitation events or storing the water off site until the pesticides degrade. However, these methods are not practical as they would be costly and difficult to design. During dry periods when groundwater sources may contribute contaminants to the surface water, augmentation of the flows by other surface water sources may assist in lowering the concentrations of selenium and minerals found in the groundwater. In addition, Quivira's management may want to further evaluate selenium concentrations in groundwater if they pursue pumping groundwater to augment surface water levels on Quivira during dry conditions.

Further reductions in pesticide concentrations entering Quivira might be made be possible by encouraging landowners off refuge to create and maintain suitable vegetative buffer areas along water ways, particularly in cropland. The USFWS Partners for Fish and Wildlife Program is working with willing landowners to establish vegetative buffers along streams, retire cropland by returning it to wetlands and grasslands, and fencing off riparian areas to keep cattle and their wastes out of streams. These actions will reduce the amount of agricultural chemicals used on surrounding lands and reduce the amount of runoff from precipitation events thereby decreasing the amount of pesticides in the surface and ground water entering Quivira. Educating landowners about Integrated Pest Management (IPM) techniques would also help to reduce the use of agricultural chemicals on surrounding lands.

Oil production on Quivira is a source of several potential pollutants in the refuge. Hydrocarbon contamination could be lessened with management practices to reduce the escape of oil production related contaminants into Quivira's environment. Lining berms around the tank batteries and oil wells would help to prevent any spills from migrating into the groundwater. Pumping out standing water from the berms surrounding the oil wells and storage tanks and disposing of it off site would also slow the migration of contaminants into Quivira's environment. Quick detection and clean-up of any spills would help to lessen impacts from spills.

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APPENDIX

Table 1. Triazine compound concentrations (in µg/l) in surface water on Quivira National Wildlife Refuge, 1996. Concentrations followed by "Low" or "High" are outside the detection range of the test kit and were interpolated by the photometer computer.

Sample	April	May	June	July	Aug.	Sept.	Oct.
Site 1	0.14	0.33	0.1	0.34	0.06	0.03 (Low)	0.05 (Low)
Site 2	0.05 (Low)	2.23 (High)	0.12	0.07	0.47	0.15	0.07
Site 3	0.03 (Low)	0.02 (Low)	0.04 (Low)	0.03 (Low)	0.03 (Low)	0.02 (Low)	0.04 (Low)
Site 4	0.06	0.32	0.03 (Low)	0.04 (Low)	0.05 (Low)	0.03 (Low)	0.04 (Low)
Site 5	0.06	0.07	0.05 (Low)	0.04 (Low)	0.03 (Low)	0.03 (Low)	0.04 (Low)
Site 6	0.03 (Low)	0.05	0.03 (Low)	0.03 (Low)	0.03 (Low)	0.03 (Low)	0.03 (Low)
Site 7	0.1	0.15	0.16	0.24	0.17	0.05 (Low)	0.06
Site 8	0.09	0.85	1.04	0.26	0.71	0.21	0.01 (Low)

Table 2. 2,4-D compound concentrations (in µg/l) in surface water on Quivira National Wildlife Refuge, 1996. Concentrations followed by "Low" or "High" are outside the detection range of the test kit and were interpolated by the photometer computer.

Sample	April	May	June	July	Aug.	Sept.	Oct.
Site 1	0.33 (Low)	0.85 (Low)	0.63 (Low)	0.97 (Low)	0.85 (Low)	0.74 (Low)	0.2 (Low)
Site 2	0.39 (Low)	0.54 (Low)	0.5 (Low)	0.89 (Low)	0.98 (Low)	0.62 (Low)	0.6 (Low)
Site 3	0.49 (Low)	0.56(Low)	0.56 (Low)	1.54 (Low)	0.9 (Low)	0.61 (Low)	0.52 (Low)
Site 4	0.45 (Low)	0.65 (Low)	0.47 (Low)	1.08 (Low)	0.7 (Low)	0.71 (Low)	0.26 (Low)
Site 5	0.38 (Low)	0.59 (Low)	0.59 (Low)	1.44 (Low)	0.91 (Low)	0.91 (Low)	0.53 (Low)
Site 6	0.56 (Low)	0.62 (Low)	0.72 (Low)	0.65 (Low)	0.95 (Low)	0.97 (Low)	0.42 (Low)
Site 7	0.47 (Low)	0.63 (Low)	0.72 (Low)	0.9 (Low)	0.77 (Low)	0.87 (Low)	0.54 (Low)
Site 8	0.47 (Low)	0.49 (Low)	0.6 (Low)	0.77(Low)	0.71 (Low)	0.77 (Low)	0.59 (Low)

Table 3. Alachlor compound concentrations (in µg/l) in surface water on Quivira National Wildlife Refuge, 1996. Concentrations followed by "Low" or "High" are outside the detection range of the test kit and were interpolated by the photometer computer. NA = Not Analyzed.

Sample	April	May	June	July	Aug.	Sept.	Oct.
Site 1	0.04 (Low)	0.08 (Low)	0.04 (Low)	0.07 (Low)	0.04 (Low)	0.03 (Low)	0.03 (Low)
Site 2	0.05 (Low)	3.11	0.14	0.05 (Low)	0.18	0.07 (Low)	0.11
Site 3	0.05 (Low)	0.02 (Low)	0.03 (Low)	0.04 (Low)	0.05 (Low)	0.03 (Low)	0.04 (Low)
Site 4	0.05 (Low)	0.03 (Low)	0.03 (Low)	0.04 (Low)	0.04 (Low)	0.04 (Low)	0.04 (Low)
Site 5	0.07 (Low)	0.02 (Low)	0.04 (Low)	0.04 Low)	0.04 (Low)	0.04 (Low)	NA
Site 6	0.04 (Low)	0.03 (Low)	0.02 (Low)	0.03 (Low)	0.03 (Low)	0.04 (Low)	0.06 (Low)
Site 7	0.04 (Low)	0.04 (Low)	0.04 (Low)	0.05 (Low)	0.04 (Low)	0.05 (Low)	0.07 (Low)
Site 8	0.04 (Low)	0.29	0.28	0.09 (Low)	0.22	0.10 (Low)	0.09 (Low)

Table 4. Selenium concentrations (in µg/l) in surface waters from Quivira National Wildlife Refuge, 1996. Shaded values are those which exceed the 2 µg/l concentration to bioaccumulate and potentially affect sensitive species of fish and aquatic birds.

Sample	June	July	August
Site 1	0.65	<0.32	<0.32
Site 2	0.90	0.60	0.90
Site 3	3.25	3.30	2.70
Site 4	<0.32	0.35	0.70
Site 5	<0.32	<0.32	<0.32
Site 6	1.60	0.70	0.90
Site 7	<0.32	<0.32	<0.32
Site 8	0.45	<0.32	<0.32

Table 5. Selenium, arsenic, mercury, copper, and lead concentrations (in µg/g dry weight) in soils collected near oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	Selenium(a)	Arsenic(a)	Mercury(b)	Copper	Lead
Eriksen	0.150	2.61	<0.085	9.00	40.00
Fair 1	0.390	3.09	<0.085	9.00	10.00
Fair B-5	0.530	1.37	<0.085	7.00	10.00
Flora B	0.110	5.56	<0.085	7.00	7.00
Sara Sleeper 1	0.210	1.70	<0.085	4.00	7.00
Sara Sleeper 3	0.560	1.55	<0.085	5.00	7.00
Sara Sleeper 4	0.350	1.22	<0.085	4.00	4.00
Sleeper 1	0.710	2.59	<0.085	6.00	9.00
Sleeper 2	0.140	2.73	<0.085	7.00	10.00
Sleeper A-1	<0.039	0.52	<0.085	2.00	3.00
Sleeper A-2	0.075	0.70	<0.085	3.00	4.00
Sleeper A-5	<0.039	0.82	<0.085	2.00	2.00
Sleeper B	0.230	3.21	<0.085	4.00	5.00
Smith Estate B-2	0.590	2.94	<0.085	9.00	20.00
Smith Estate B-3	0.290	1.80	<0.085	5.00	6.00
Smith Estate B-4	0.300	3.08	<0.085	6.00	8.00
Tank Battery	0.180	1.07	<0.085	4.00	6.00
Wolf A-1	0.120	2.21	<0.085	7.00	7.00
Wolf A-2	0.056	1.95	<0.085	3.00	7.00
Wolf A-3	0.150	2.42	<0.085	9.00	10.00
Wolf A-4	0.150	2.58	<0.085	10.00	10.00
Wolf A-5	0.100	1.28	<0.085	7.00	20.00
Wolf Tank Battery	0.110	1.84	<0.085	4.00	7.00

Concentrations determined by semi-quantitative scan using ICP-MS
(a) Arsenic and selenium determined by flow injection hydride generation atomic absorption spectrometry
(b) Mercury determined by flow injection cold vapor atomic adsorption spectrometry

Table 6. Selenium, arsenic, mercury, copper, and lead concentrations (in µg/g dry weight) in composite samples of terrestrial invertebrates collected on Quivira National Wildife Refuge, 1996.

Sample	Selenium(a)	Arsenic(a)	Mercury(b)	Copper	Lead
Insect 1	0.15	0.38	0.03	20.00	<1.00
Insect 2	0.18	0.10	0.12	40.00	<1.00
Insect 3	0.84	0.55	0.12	20.00	1.00
Insect 4	1.10	0.42	0.10	20.00	1.00
Insect 5	1.00	0.53	0.11	10.00	1.00
Insect 6	0.98	0.72	0.07	20.00	1.00
Insect 7	1.10	0.29	0.14	20.00	1.00

Concentrations determined by semi-quantitative scan using ICP-MS
(a) Arsenic and selenium determined by flow injection hydride generation atomic absorption spectrometry
(b) Mercury determined by flow injection cold vapor atomic adsorption spectrometry

Table 7. Selenium, arsenic, mercury, copper, and lead concentrations (in µg/g dry weight) in fish collected on Quivira National Wildife Refuge, 1996.

Sample	Selenium(a)	Arsenic(a)	Mercury(b)	Copper	Lead
Carp 1	1.40	0.39	0.12	4.00	<1.00
Carp 2	2.30	0.73	0.20	6.00	<1.00
Carp 3	1.90	0.38	0.20	7.00	<1.00
Carp 4	0.90	0.25	0.10	4.00	<1.00
Carp 5	1.10	0.34	0.24	4.00	<1.00
*Forage Fish 1	1.90	0.63	0.12	4.00	<1.00
*Forage Fish 2	3.50	0.42	0.23	3.00	<1.00
*Forage Fish 3	2.00	0.80	0.23	4.00	<1.00
*Forage Fish 4	3.70	0.33	0.31	2.00	<1.00
*Forage Fish 5	1.40	0.82	0.20	4.00	<1.00
*Forage Fish 6	3.20	0.65	0.11	4.00	<1.00
*Forage Fish 7	1.20	0.65	0.13	4.00	<1.00
*Forage Fish 8	2.30	1.50	0.12	10.00	2.00

Concentrations determined by semi-quantitative scan using ICP-MS
(a) Arsenic and selenium determined by flow injection hydride generation atomic absorption spectrometry
(b) Mercury determined by flow injection cold vapor atomic adsorption spectrometry
*Forage fish were composed of composite samples of unidentified species.

Table 8. Trace element concentrations (in µg/g dry weight) in soils collected near oil production facilities on Quivira National Wildlife Refuge, 1996. Concentrations determined by semi-quantitative scan.

Site Name	Aluminum	Antimony	Barium	Beryllium	Bismuth	Cadmium	Calcium	Cerium	Cesium	Chromium
Eriksen	4000.00	<0.10	40.00	<1.00	<1.00	0.50	4000.00	10.00	<1.00	7.00
Fair 1	5000.00	0.20	200.00	<1.00	<1.00	0.60	54000.00	20.00	<1.00	5.00
Fair B-5	8000.00	<0.10	60.00	<1.00	<1.00	0.50	9000.00	20.00	<1.00	8.00
Flora B	9000.00	0.20	90.00	<1.00	<1.00	0.20	2000.00	20.00	<1.00	9.00
Sara Sleeper 1	3000.00	<0.10	30.00	<1.00	<1.00	0.60	7000.00	10.00	<1.00	3.00
Sara Sleeper 3	4000.00	<0.10	90.00	<1.00	<1.00	0.40	28000.00	10.00	<1.00	4.00
Sara Sleeper 4	3000.00	<0.10	100.00	<1.00	<1.00	0.40	40000.00	10.00	<1.00	3.00
Sleeper 1	4000.00	<0.10	200.00	<1.00	<1.00	0.50	89000.00	20.00	<1.00	5.00
Sleeper 2	2000.00	<0.10	50.00	<1.00	<1.00	0.30	7000.00	10.00	<1.00	4.00
Sleeper A-1	900.00	<0.10	20.00	<1.00	<1.00	0.30	5000.00	5.00	<1.00	2.00
Sleeper A-2	2000.00	<0.10	30.00	<1.00	<1.00	0.30	8000.00	7.00	<1.00	2.00
Sleeper A-5	600.00	<0.10	8.00	<1.00	<1.00	0.20	300.00	5.00	<1.00	2.00
Sleeper B	5000.00	<0.10	50.00	<1.00	<1.00	0.20	8000.00	20.00	<1.00	5.00
Smith Estate B-2	7000.00	0.20	400.00	<1.00	<1.00	0.30	46000.00	20.00	<1.00	10.00
Smith Estate B-3	5000.00	<0.10	200.00	<1.00	<1.00	0.40	38000.00	20.00	<1.00	6.00
Smith Estate B-4	6000.00	<0.10	200.00	<1.00	<1.00	0.40	30000.00	20.00	<1.00	9.00
Tank Battery	2000.00	<0.10	30.00	<1.00	<1.00	0.40	3000.00	10.00	<1.00	4.00
Wolf A-1	7000.00	<0.10	70.00	<1.00	<1.00	0.20	59000.00	10.00	<1.00	7.00
Wolf A-2	3000.00	<0.10	50.00	<1.00	<1.00	0.40	30000.00	8.00	<1.00	3.00
Wolf A-3	5000.00	<0.10	70.00	<1.00	<1.00	0.50	45000.00	10.00	<1.00	6.00
Wolf A-4	5000.00	<0.10	80.00	<1.00	<1.00	0.50	41000.00	10.00	<1.00	5.00
Wolf A-5	5000.00	<0.10	90.00	<1.00	<1.00	0.60	78000.00	10.00	<1.00	5.00
Wolf Tank Battery	3000.00	<0.10	70.00	<1.00	<1.00	0.40	25000.00	10.00	<1.00	3.00

Table 8. Continued

Site Name	Cobalt	Dysprosium	Erbium	Europium	Gadolinium	Gallium	Germanium	Gold	Hafnium	Holmium
Eriksen	2.00	0.90	0.40	0.20	1.00	2.00	<0.10	<0.10	<0.10	0.20
Fair 1	3.00	1.00	0.50	0.40	2.00	2.00	<0.10	<0.10	<0.10	0.20
Fair B-5	4.00	2.00	0.70	0.40	2.00	3.00	<0.10	<0.10	<0.10	0.20
Flora B	4.00	2.00	0.60	0.40	3.00	3.00	<0.10	<0.10	0.20	0.20
Sara Sleeper 1	2.00	0.80	0.30	0.20	1.00	1.00	<0.10	<0.10	<0.10	0.10
Sara Sleeper 3	2.00	1.00	0.40	0.30	2.00	2.00	<0.10	<0.10	<0.10	0.20
Sara Sleeper 4	2.00	0.70	0.30	0.20	1.00	1.00	<0.10	<0.10	<0.10	0.10
Sleeper 1	3.00	1.00	0.40	0.30	1.00	2.00	<0.10	<0.10	<0.10	0.20
Sleeper 2	2.00	0.90	0.40	0.20	1.00	1.00	<0.10	<0.10	<0.10	0.20
Sleeper A-1	0.60	0.30	0.10	<0.10	0.60	0.40	<0.10	<0.10	<0.10	<0.10
Sleeper A-2	0.80	0.50	0.20	0.20	0.90	0.70	<0.10	0.20	<0.10	<0.10
Sleeper A-5	0.90	0.50	0.20	0.20	0.80	0.40	<0.10	<0.10	<0.10	<0.10
Sleeper B	2.00	1.00	0.60	0.30	2.00	2.00	<0.10	<0.10	<0.10	0.20
Smith Estate B-2	3.00	1.00	0.60	0.40	2.00	3.00	<0.10	<0.10	<0.10	0.20
Smith Estate B-3	2.00	1.00	0.50	0.30	2.00	2.00	<0.10	<0.10	<0.10	0.20
Smith Estate B-4	3.00	2.00	0.70	0.40	2.00	3.00	<0.10	0.20	0.10	0.30
Tank Battery	2.00	0.90	0.40	0.20	1.00	1.00	<0.10	<0.10	<0.10	0.20
Wolf A-1	3.00	1.00	0.50	0.30	2.00	3.00	<0.10	0.20	0.10	0.20
Wolf A-2	2.00	0.50	0.20	0.20	0.80	1.00	<0.10	<0.10	<0.10	<0.10
Wolf A-3	2.00	1.00	0.40	0.30	1.00	2.00	<0.10	<0.10	<0.10	0.20
Wolf A-4	3.00	1.00	0.40	0.30	1.00	2.00	<0.10	<0.10	0.10	0.20
Wolf A-5	2.00	0.90	0.40	0.30	1.00	2.00	<0.10	<0.10	<0.10	0.20
Wolf Tank Battery	2.00	0.80	0.30	0.20	1.00	1.00	<0.10	<0.10	<0.10	0.10

Table 8. Continued

Site Name	Indium	Iridium	Iron	Lanthanum	Lithium	Lutetium	Magnesium	Manganese	Molybdenum
Eriksen	<1.00	<0.10	5000.00	6.00	5.00	<0.10	1000.00	100.00	0.60
Fair 1	<1.00	<0.10	6000.00	7.00	9.00	<0.10	3000.00	800.00	0.20
Fair B-5	<1.00	<0.10	6000.00	10.00	10.00	<0.10	7000.00	300.00	0.20
Flora B	<1.00	<0.10	8000.00	10.00	7.00	<0.10	2000.00	300.00	0.50
Sara Sleeper 1	<1.00	<0.10	2000.00	5.00	4.00	<0.10	2000.00	100.00	0.20
Sara Sleeper 3	<1.00	<0.10	4000.00	7.00	9.00	<0.10	4000.00	200.00	0.20
Sara Sleeper 4	<1.00	<0.10	3000.00	5.00	4.00	<0.10	2000.00	100.00	0.30
Sleeper 1	<1.00	<0.10	4000.00	7.00	5.00	<0.10	2000.00	600.00	0.40
Sleeper 2	<1.00	<0.10	3000.00	6.00	2.00	<0.10	1000.00	200.00	0.20
Sleeper A-1	<1.00	<0.10	1000.00	3.00	2.00	<0.10	800.00	40.00	<0.10
Sleeper A-2	<1.00	<0.10	2000.00	4.00	3.00	<0.10	1000.00	80.00	0.20
Sleeper A-5	<1.00	<0.10	5000.00	4.00	<1.00	<0.10	100.00	30.00	0.20
Sleeper B	<1.00	<0.10	4000.00	8.00	5.00	<0.10	2000.00	100.00	0.40
Smith Estate B-2	<1.00	<0.10	6000.00	9.00	7.00	<0.10	3000.00	100.00	0.50
Smith Estate B-3	<1.00	<0.10	5000.00	8.00	8.00	<0.10	3000.00	100.00	0.50
Smith Estate B-4	<1.00	<0.10	6000.00	10.00	7.00	<0.10	2000.00	100.00	0.60
Tank Battery	<1.00	<0.10	5000.00	6.00	3.00	<0.10	900.00	100.00	0.20
Wolf A-1	<1.00	<0.10	6000.00	7.00	20.00	<0.10	8000.00	600.00	1.00
Wolf A-2	<1.00	<0.10	3000.00	4.00	6.00	<0.10	3000.00	200.00	0.20
Wolf A-3	<1.00	<0.10	5000.00	6.00	10.00	<0.10	4000.00	300.00	2.00
Wolf A-4	<1.00	<0.10	5000.00	6.00	9.00	<0.10	4000.00	500.00	1.00
Wolf A-5	<1.00	<0.10	4000.00	6.00	10.00	<0.10	4000.00	300.00	0.50
Wolf Tank Battery	<1.00	<0.10	3000.00	6.00	6.00	<0.10	3000.00	100.00	0.30

Table 8. Continued

Site Name	Neodymium	Nickel	Niobium	Osmium	Palladium	Platinum	Potassium	Praseodymium	Rhenium
Eriksen	7.00	6.00	<1.00	<0.10	<0.10	<0.10	2000.00	2.00	<0.10
Fair 1	9.00	7.00	<1.00	<0.10	<0.10	<0.10	2000.00	3.00	<0.10
Fair B-5	10.00	7.00	<1.00	<0.10	<0.10	<0.10	3000.00	4.00	<0.10
Flora B	10.00	9.00	<1.00	<0.10	<0.10	<0.10	1000.00	3.00	<0.10
Sara Sleeper 1	6.00	3.00	<1.00	<0.10	<0.10	<0.10	1000.00	2.00	<0.10
Sara Sleeper 3	7.00	4.00	<1.00	<0.10	<0.10	<0.10	1000.00	2.00	<0.10
Sara Sleeper 4	6.00	4.00	<1.00	<0.10	<0.10	<0.10	600.00	2.00	<0.10
Sleeper 1	8.00	4.00	<1.00	<0.10	<0.10	<0.10	900.00	2.00	<0.10
Sleeper 2	7.00	3.00	<1.00	<0.10	<0.10	<0.10	900.00	2.00	<0.10
Sleeper A-1	3.00	1.00	<1.00	<0.10	<0.10	<0.10	400.00	0.80	<0.10
Sleeper A-2	4.00	2.00	<1.00	<0.10	<0.10	<0.10	600.00	1.00	<0.10
Sleeper A-5	5.00	2.00	<1.00	<0.10	<0.10	<0.10	200.00	1.00	<0.10
Sleeper B	9.00	5.00	<1.00	<0.10	<0.10	<0.10	1000.00	3.00	<0.10
Smith Estate B-2	10.00	8.00	<1.00	<0.10	<0.10	<0.10	1000.00	3.00	<0.10
Smith Estate B-3	10.00	5.00	<1.00	<0.10	<0.10	<0.10	1000.00	3.00	<0.10
Smith Estate B-4	10.00	7.00	<1.00	<0.10	<0.10	<0.10	2000.00	3.00	<0.10
Tank Battery	7.00	3.00	<1.00	<0.10	<0.10	<0.10	800.00	2.00	<0.10
Wolf A-1	8.00	6.00	<1.00	<0.10	<0.10	<0.10	2000.00	3.00	<0.10
Wolf A-2	4.00	3.00	<1.00	<0.10	<0.10	<0.10	700.00	1.00	<0.10
Wolf A-3	7.00	5.00	<1.00	<0.10	<0.10	<0.10	2000.00	2.00	<0.10
Wolf A-4	7.00	7.00	<1.00	<0.10	<0.10	<0.10	2000.00	2.00	<0.10
Wolf A-5	6.00	5.00	<1.00	<0.10	<0.10	<0.10	1000.00	2.00	<0.10
Wolf Tank Battery	6.00	4.00	<1.00	<0.10	<0.10	<0.10	900.00	2.00	<0.10

Table 8. Continued

Site Name	Rubidium	Ruthenium	Samarium	Silver	Sodium	Strontium	Tantalum	Tellurium	Terbium	Thallium
Eriksen	7.00	<1.00	1.00	<0.10	300.00	20.00	<0.10	<0.10	0.20	<0.10
Fair 1	10.00	<1.00	2.00	<0.10	3000.00	400.00	<0.10	<0.10	0.20	0.10
Fair B-5	20.00	<1.00	2.00	<0.10	4000.00	60.00	<0.10	<0.10	0.30	<0.10
Flora B	10.00	<1.00	2.00	<0.10	1000.00	20.00	<0.10	<0.10	0.30	0.10
Sara Sleeper 1	5.00	<1.00	1.00	<0.10	2000.00	40.00	<0.10	<0.10	0.20	<0.10
Sara Sleeper 3	8.00	<1.00	2.00	<0.10	2000.00	100.00	<0.10	<0.10	0.20	<0.10
Sara Sleeper 4	5.00	<1.00	1.00	<0.10	400.00	100.00	<0.10	<0.10	0.20	<0.10
Sleeper 1	7.00	<1.00	1.00	<0.10	300.00	200.00	<0.10	<0.10	0.20	<0.10
Sleeper 2	6.00	<1.00	1.00	<0.10	2000.00	20.00	<0.10	<0.10	0.20	<0.10
Sleeper A-1	2.00	<1.00	0.50	<0.10	1000.00	20.00	<0.10	<0.10	<0.10	<0.10
Sleeper A-2	3.00	<1.00	0.80	<0.10	3000.00	40.00	<0.10	<0.10	<0.10	<0.10
Sleeper A-5	1.00	<1.00	0.80	<0.10	100.00	2.00	<0.10	<0.10	<0.10	<0.10
Sleeper B	9.00	<1.00	2.00	<0.10	5000.00	30.00	<0.10	<0.10	0.20	<0.10
Smith Estate B-2	10.00	<1.00	2.00	<0.10	300.00	100.00	<0.10	<0.10	0.30	<0.10
Smith Estate B-3	8.00	<1.00	2.00	<0.10	600.00	100.00	<0.10	<0.10	0.20	<0.10
Smith Estate B-4	10.00	<1.00	2.00	<0.10	600.00	70.00	<0.10	<0.10	0.30	0.10
Tank Battery	6.00	<1.00	1.00	<0.10	1000.00	10.00	<0.10	<0.10	0.20	<0.10
Wolf A-1	10.00	<1.00	2.00	<0.10	12000.00	300.00	<0.10	<0.10	0.20	0.10
Wolf A-2	5.00	<1.00	0.80	<0.10	4000.00	100.00	<0.10	<0.10	0.10	<0.10
Wolf A-3	10.00	<1.00	1.00	<0.10	7000.00	200.00	<0.10	<0.10	0.20	<0.10
Wolf A-4	10.00	<1.00	1.00	<0.10	7000.00	200.00	<0.10	<0.10	0.20	0.10
Wolf A-5	9.00	<1.00	1.00	<0.10	12000.00	300.00	<0.10	<0.10	0.20	<0.10
Wolf Tank Battery	6.00	<1.00	1.00	<0.10	4000.00	100.00	<0.10	<0.10	0.20	<0.10

Table 8. Continued

Site Name	Thulium	Tin	Titanium	Tungsten	Uranium	Vanadium	Ytterbium	Yttrium	Zinc	Zirconium
Eriksen	<0.10	0.70	30.00	<0.10	<1.00	10.00	0.40	3.00	30.00	3.00
Fair 1	<0.10	0.50	40.00	<0.10	<1.00	10.00	0.50	5.00	30.00	3.00
Fair B-5	<0.10	0.60	50.00	<0.10	<1.00	10.00	0.70	7.00	30.00	3.00
Flora B	<0.10	0.50	60.00	<0.10	<1.00	20.00	0.60	6.00	10.00	5.00
Sara Sleeper 1	<0.10	0.40	30.00	<0.10	<1.00	6.00	0.30	3.00	5.00	2.00
Sara Sleeper 3	<0.10	0.40	40.00	<0.10	<1.00	8.00	0.40	4.00	9.00	3.00
Sara Sleeper 4	<0.10	0.30	30.00	<0.10	<1.00	7.00	0.30	3.00	<1.00	2.00
Sleeper 1	<0.10	0.80	30.00	<0.10	<1.00	10.00	0.40	4.00	10.00	1.00
Sleeper 2	<0.10	0.50	30.00	<0.10	<1.00	8.00	0.30	3.00	30.00	2.00
Sleeper A-1	<0.10	0.30	20.00	<0.10	<1.00	3.00	0.10	1.00	<1.00	<1.00
Sleeper A-2	<0.10	0.40	20.00	<0.10	<1.00	5.00	0.20	2.00	3.00	1.00
Sleeper A-5	<0.10	0.50	20.00	<0.10	<1.00	6.00	0.20	2.00	<1.00	1.00
Sleeper B	<0.10	0.40	30.00	<0.10	<1.00	10.00	0.60	6.00	4.00	3.00
Smith Estate B-2	<0.10	0.40	40.00	<0.10	<1.00	20.00	0.60	5.00	20.00	3.00
Smith Estate B-3	<0.10	0.40	40.00	<0.10	<1.00	10.00	0.50	5.00	4.00	2.00
Smith Estate B-4	<0.10	0.50	40.00	<0.10	<1.00	20.00	0.70	6.00	10.00	4.00
Tank Battery	<0.10	0.30	40.00	<0.10	<1.00	8.00	0.30	3.00	3.00	2.00
Wolf A-1	<0.10	0.60	50.00	<0.10	<1.00	10.00	0.50	5.00	20.00	4.00
Wolf A-2	<0.10	0.40	30.00	<0.10	<1.00	6.00	0.20	2.00	<1.00	2.00
Wolf A-3	<0.10	0.50	50.00	<0.10	<1.00	10.00	0.40	4.00	10.00	3.00
Wolf A-4	<0.10	0.90	40.00	<0.10	<1.00	10.00	0.40	3.00	30.00	4.00
Wolf A-5	<0.10	0.50	40.00	<0.10	<1.00	10.00	0.40	4.00	30.00	3.00
Wolf Tank Battery	<0.10	0.40	30.00	<0.10	<1.00	8.00	0.30	3.00	4.00	2.00

Table 9. Trace metal concentrations (in µg/g dry weight) in composite invertebrate samples collected on Quivira National Wildlife Refuge, 1996. Concentrations determined by semi-quantitative scan.

Sample	Aluminum	Antimony	Barium	Beryllium	Bismuth	Cadmium	Calcium	Cerium	Cesium	Chromium
Insect 1	30.00	<0.10	10.00	<1.00	<1.00	<0.10	2000.00	<0.10	<1.00	1.00
Insect 2	30.00	<0.10	5.00	<1.00	<1.00	<0.10	800.00	<0.10	<1.00	2.00
Insect 3	800.00	<0.10	20.00	<1.00	<1.00	0.30	7000.00	3.00	<1.00	2.00
Insect 4	600.00	<0.10	20.00	<1.00	<1.00	0.30	6000.00	2.00	<1.00	2.00
Insect 5	500.00	<0.10	20.00	<1.00	<1.00	0.30	5000.00	3.00	<1.00	1.00
Insect 6	500.00	<0.10	10.00	<1.00	<1.00	0.30	7000.00	2.00	<1.00	2.00
Insect 7	200.00	0.20	10.00	<1.00	<1.00	0.20	3000.00	1.00	<1.00	1.00

Sample	Cobalt	Dysprosium	Erbium	Europium	Gadolinium	Gallium	Germanium	Gold	Hafnium	Holmium
Insect 1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Insect 2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Insect 3	0.40	0.20	<0.10	<0.10	0.30	0.30	<0.10	<0.10	<0.10	<0.10
Insect 4	0.40	0.20	<0.10	<0.10	0.20	0.20	<0.10	<0.10	<0.10	<0.10
Insect 5	0.40	0.20	<0.10	<0.10	0.30	0.20	<0.10	0.20	<0.10	<0.10
Insect 6	0.50	0.20	<0.10	<0.10	0.30	0.20	<0.10	<0.10	<0.10	<0.10
Insect 7	0.20	<0.10	<0.10	<0.10	0.10	0.10	<0.10	<0.10	<0.10	<0.10

Sample	Indium	Iridium	Iron	Lanthanum	Lithium	Lutetium	Magnesium	Manganese	Molybdenum	Neodymium
Insect 1	<1.00	<0.10	90.00	<0.10	1.00	<0.10	1000.00	70.00	2.00	<0.10
Insect 2	<1.00	<0.10	200.00	<0.10	<1.00	<0.10	900.00	20.00	2.00	<0.10
Insect 3	<1.00	<0.10	600.00	1.00	2.00	<0.10	2000.00	30.00	0.60	1.00
Insect 4	<1.00	<0.10	500.00	0.80	2.00	<0.10	2000.00	30.00	0.70	1.00
Insect 5	<1.00	<0.10	600.00	2.00	2.00	<0.10	1000.00	30.00	0.70	2.00
Insect 6	<1.00	<0.10	600.00	1.00	2.00	<0.10	2000.00	30.00	0.80	1.00
Insect 7	<1.00	<0.10	400.00	0.60	1.00	<0.10	1000.00	20.00	0.70	0.70

Sample	Nickel	Niobium	Osmium	Palladium	Platinum	Potassium	Praseodymium	Rhenium	Rubidium	Ruthenium
Insect 1	<1.00	<1.00	<0.10	<0.10	<0.10	27000.00	<0.10	<0.10	0.80	<1.00
Insect 2	<1.00	<1.00	<0.10	<0.10	<0.10	13000.00	<0.10	<0.10	1.00	<1.00
Insect 3	<1.00	<1.00	<0.10	<0.10	<0.10	5000.00	0.40	<0.10	2.00	<1.00
Insect 4	<1.00	<1.00	<0.10	<0.10	<0.10	7000.00	0.30	<0.10	2.00	<1.00
Insect 5	<1.00	<1.00	<0.10	<0.10	<0.10	5000.00	0.50	<0.10	1.00	<1.00
Insect 6	<1.00	<1.00	<0.10	<0.10	<0.10	5000.00	0.30	<0.10	1.00	<1.00
Insect 7	<1.00	<1.00	<0.10	<0.10	<0.10	5000.00	0.20	<0.10	1.00	<1.00

Table 9. Continued

Sample	Samarium	Silver	Sodium	Strontium	Tantalum	Tellurium	Terbium	Thallium	Thulium	Tin
Insect 1	<0.10	<0.10	1000.00	10.00	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Insect 2	<0.10	<0.10	2000.00	7.00	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Insect 3	0.30	<0.10	6000.00	50.00	<0.10	<0.10	<0.10	<0.10	<0.10	7.00
Insect 4	0.20	<0.10	8000.00	40.00	<0.10	<0.10	<0.10	<0.10	<0.10	7.00
Insect 5	0.30	<0.10	6000.00	30.00	<0.10	<0.10	<0.10	<0.10	<0.10	9.00
Insect 6	0.20	<0.10	10000.00	40.00	<0.10	<0.10	<0.10	<0.10	<0.10	7.00
Insect 7	0.10	<0.10	5000.00	20.00	<0.10	<0.10	<0.10	<0.10	<0.10	10.00

Sample	Titanium	Tungsten	Uranium	Vanadium	Ytterbium	Yttrium	Zinc	Zirconium
Insect 1	20.00	<0.10	<1.00	1.00	<0.10	<1.00	100.00	<1.00
Insect 2	20.00	<0.10	<1.00	2.00	<0.10	<1.00	200.00	<1.00
Insect 3	20.00	<0.10	<1.00	3.00	<0.10	<1.00	80.00	<1.00
Insect 4	20.00	<0.10	<1.00	3.00	<0.10	<1.00	90.00	<1.00
Insect 5	20.00	<0.10	<1.00	3.00	<0.10	<1.00	60.00	<1.00
Insect 6	20.00	<0.10	<1.00	3.00	<0.10	<1.00	70.00	<1.00
Insect 7	20.00	<0.10	<1.00	2.00	<0.10	<1.00	80.00	<1.00

Table 10. Trace metal concentrations (in µg/g dry weight, whole body) in fish collected on Quivira National Wildlife Refuge, 1996. Concentrations determined by semi-quantitative scan.

Sample	Aluminum	Antimony	Barium	Beryllium	Bismuth	Cadmium	Calcium	Cerium	Cesium	Chromium
Carp 1	40.0	<0.1	10.0	<1.0	<1.0	<0.1	40000.0	<0.1	<1.0	2.0
Carp 2	20.0	<0.1	9.0	<1.0	<1.0	<0.1	29000.0	<0.1	<1.0	5.0
Carp 3	20.0	<0.1	10.0	<1.0	<1.0	<0.1	42000.0	<0.1	<1.0	1.0
Carp 4	100.0	<0.1	20.0	<1.0	<1.0	<0.1	56000.0	0.2	<1.0	2.0
Carp 5	60.0	<0.1	20.0	<1.0	<1.0	<0.1	63000.0	<0.1	<1.0	5.0
*Forage Fish 1	40.0	<0.1	20.0	<1.0	<1.0	<0.1	37000.0	<0.1	<1.0	3.0
*Forage Fish 2	100.0	<0.1	60.0	<1.0	<1.0	<0.1	50000.0	0.2	<1.0	3.0
*Forage Fish 3	40.0	<0.1	10.0	<1.0	<1.0	<0.1	30000.0	<0.1	<1.0	2.0
*Forage Fish 4	100.0	<0.1	20.0	<1.0	<1.0	<0.1	62000.0	0.1	<1.0	2.0
*Forage Fish 5	500.0	<0.1	40.0	<1.0	<1.0	<0.1	38000.0	1.0	<1.0	3.0
*Forage Fish 6	100.0	<0.1	30.0	<1.0	<1.0	<0.1	43000.0	0.2	<1.0	3.0
*Forage Fish 7	200.0	<0.1	40.0	<1.0	<1.0	<0.1	40000.0	0.6	<1.0	20.0
*Forage Fish 8	400.0	0.2	30.0	<1.0	<1.0	0.1	33000.0	0.8	<1.0	2.0

Sample	Cobalt	Dysprosium	Erbium	Europium	Gadolinium	Gallium	Germanium	Gold	Hafnium	Holmium
Carp 1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Carp 2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carp 3	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carp 4	0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
Carp 5	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
*Forage Fish 1	0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
*Forage Fish 2	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
*Forage Fish 3	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
*Forage Fish 4	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
*Forage Fish 5	0.3	0.1	<0.1	<0.1	0.2	0.3	<0.1	<0.1	<0.1	<0.1
*Forage Fish 6	0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
*Forage Fish 7	0.2	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
*Forage Fish 8	0.4	<0.1	<0.1	<0.1	0.1	0.2	<0.1	0.2	<0.1	<0.1

*Forage fish were composed of composite samples of unidentified species.

Table 10. Continued

Sample	Indium	Iridium	Iron	Lanthanum	Lithium	Lutetium	Magnesium	Manganese	Molybdenum
Carp 1	<1.0	<0.1	200.0	<0.1	<1.0	<0.1	1000.0	10.0	<0.1
Carp 2	<1.0	<0.1	200.0	<0.1	<1.0	<0.1	1000.0	9.0	0.2
Carp 3	<1.0	<0.1	200.0	<0.1	<1.0	<0.1	1000.0	10.0	<0.1
Carp 4	<1.0	<0.1	300.0	<0.1	<1.0	<0.1	2000.0	10.0	<0.1
Carp 5	<1.0	<0.1	300.0	<0.1	<1.0	<0.1	2000.0	30.0	0.1
*Forage Fish 1	<1.0	<0.1	700.0	<0.1	<1.0	<0.1	2000.0	30.0	0.2
*Forage Fish 2	<1.0	<0.1	200.0	0.1	<1.0	<0.1	2000.0	30.0	0.2
*Forage Fish 3	<1.0	<0.1	300.0	<0.1	<1.0	<0.1	1000.0	20.0	0.3
*Forage Fish 4	<1.0	<0.1	300.0	<0.1	<1.0	<0.1	2000.0	30.0	0.2
*Forage Fish 5	<1.0	<0.1	600.0	0.5	1.0	<0.1	2000.0	40.0	0.2
*Forage Fish 6	<1.0	<0.1	200.0	0.1	<1.0	<0.1	2000.0	10.0	0.2
*Forage Fish 7	<1.0	<0.1	500.0	0.3	<1.0	<0.1	1000.0	40.0	0.4
*Forage Fish 8	<1.0	<0.1	400.0	0.4	2.0	<0.1	3000.0	30.0	0.3

Sample	Neodymium	Nickel	Niobium	Osmium	Palladium	Platinum	Potassium	Praseodymium	Rhenium
Carp 1	<0.1	1.0	<1.0	<0.1	<0.1	<0.1	13000.0	<0.1	<0.1
Carp 2	<0.1	2.0	<1.0	<0.1	<0.1	<0.1	14000.0	<0.1	<0.1
Carp 3	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	12000.0	<0.1	<0.1
Carp 4	<0.1	2.0	<1.0	<0.1	<0.1	<0.1	12000.0	<0.1	<0.1
Carp 5	<0.1	2.0	<1.0	<0.1	<0.1	<0.1	15000.0	<0.1	<0.1
*Forage Fish 1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	15000.0	<0.1	<0.1
*Forage Fish 2	0.1	<1.0	<1.0	<0.1	<0.1	<0.1	14000.0	<0.1	<0.1
*Forage Fish 3	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	17000.0	<0.1	<0.1
*Forage Fish 4	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	14000.0	<0.1	<0.1
*Forage Fish 5	0.6	<1.0	<1.0	<0.1	<0.1	<0.1	15000.0	0.2	<0.1
*Forage Fish 6	0.1	<1.0	<1.0	<0.1	<0.1	<0.1	15000.0	<0.1	<0.1
*Forage Fish 7	0.3	4.0	<1.0	<0.1	<0.1	<0.1	16000.0	<0.1	<0.1
Forage Fish 8	0.5	<1.0	<1.0	<0.1	<0.1	<0.1	17000.0	0.1	<0.1

*Forage fish were composed of composite samples of unidentified species.

Table 10. Continued

Sample	Rubidium	Ruthenium	Samarium	Silver	Sodium	Strontium	Tantalum	Tellurium	Terbium	Thallium
Carp 1	2.0	<1.0	<0.1	<0.1	4000.0	200.000	<0.1	<0.1	<0.1	<0.1
Carp 2	3.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
Carp 3	2.0	<1.0	<0.1	<0.1	4000.0	200.000	<0.1	<0.1	<0.1	<0.1
Carp 4	0.9	<1.0	<0.1	<0.1	5000.0	500.000	<0.1	<0.1	<0.1	<0.1
Carp 5	2.0	<1.0	<0.1	<0.1	6000.0	300.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 1	3.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 2	2.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 3	3.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 4	3.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 5	4.0	<1.0	0.1	<0.1	6000.0	300.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 6	3.0	<1.0	<0.1	<0.1	5000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 7	3.0	<1.0	<0.1	<0.1	6000.0	200.000	<0.1	<0.1	<0.1	<0.1
*Forage Fish 8	5.0	<1.0	<0.1	<0.1	13000.0	400.000	<0.1	<0.1	<0.1	<0.1

Sample	Thulium	Tin	Titanium	Tungsten	Uranium	Vanadium	Ytterbium	Yttrium	Zinc	Zirconium
Carp 1	<0.1	30.0	40.0	<0.1	<1.0	1.0	<0.1	<1.0	200.0	<1.0
Carp 2	<0.1	<0.1	40.0	<0.1	<1.0	2.0	<0.1	<1.0	200.0	<1.0
Carp 3	<0.1	10.0	50.0	<0.1	<1.0	1.0	<0.1	<1.0	200.0	<1.0
Carp 4	<0.1	30.0	60.0	<0.1	<1.0	2.0	<0.1	<1.0	200.0	<1.0
Carp 5	<0.1	40.0	60.0	<0.1	<1.0	1.0	<0.1	<1.0	200.0	<1.0
*Forage Fish 1	<0.1	<0.1	40.0	<0.1	<1.0	1.0	<0.1	<1.0	200.0	<1.0
*Forage Fish 2	<0.1	0.1	50.0	<0.1	<1.0	1.0	<0.1	<1.0	200.0	<1.0
*Forage Fish 3	<0.1	<0.1	40.0	<0.1	<1.0	1.0	<0.1	<1.0	100.0	<1.0
*Forage Fish 4	<0.1	<0.1	70.0	<0.1	<1.0	2.0	<0.1	<1.0	200.0	2.0
*Forage Fish 5	<0.1	<0.1	50.0	<0.1	<1.0	2.0	<0.1	<1.0	100.0	<1.0
*Forage Fish 6	<0.1	<0.1	40.0	<0.1	<1.0	2.0	<0.1	<1.0	200.0	<1.0
*Forage Fish 7	<0.1	<0.1	60.0	<0.1	<1.0	2.0	<0.1	<1.0	400.0	<1.0
*Forage Fish 8	<0.1	0.3	50.0	<0.1	<1.0	2.0	<0.1	<1.0	100.0	2.0

*Forage fish were composed of composite samples of unidentified species.

Table 11. Composition of soil samples collected near oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	% Moisture	%Sand	%Silt	%Clay	Soil Type	%Organic Carbon
Eriksen	14.70	67.0	13.0	20.0	sandy clay loam	1.92
Fair 1	18.00	63.0	7.2	29.8	sandy clay loam	1.56
Fair B-5	19.00	37.0	20.0	43.0	clay	2.14
Flora B	11.20	72.0	10.2	17.8	sandy loam	0.68
Sara Sleeper 1	55.30	69.2	7.8	23.0	sandy clay loam	1.02
Sara Sleeper 3	24.30	64.0	13.0	23.0	sandy clay loam	1.07
Sara Sleeper 4	17.80	75.2	18.0	6.8	loamy sand	1.46
Sleeper 1	15.80	58.0	16.0	26.0	sandy clay loam	2.06
Sleeper 2	9.43	71.0	9.0	20.0	sandy clay loam/sandy loam	1.46
Sleeper A-1	20.40	81.2	7.8	11.0	loamy sand/sandy loam	0.94
Sleeper A-2	25.20	89.2	9.0	1.8	sand	1.20
Sleeper A-5	1.80	88.0	15.0	0.0	sand/loamy sand	0.34
Sleeper B	16.80	58.0	12.0	30.0	sandy clay loam	0.74
Smith Estate B-2	18.00	53.5	19.0	27.5	sandy clay loam	2.41
Smith Estate B-3	18.80	55.5	20.0	24.5	sandy clay loam	1.20
Smith Estate B-4	21.40	52.2	23.0	24.5	sandy clay loam	1.62
Tank Battery	20.00	65.0	4.2	30.8	sandy clay loam	0.62
Wolf A-1	42.60	53.2	16.8	30.0	sandy clay loam	1.22
Wolf A-2	30.60	69.2	10.8	20.0	sandy clay loam/sandy loam	0.58
Wolf A-3	37.00	82.2	11.0	6.8	loamy sand	0.94
Wolf A-4	38.20	65.5	10.0	24.5	sandy clay loam	5.51
Wolf A-5	23.40	70.5	8.0	21.5	sandy clay loam	0.30
Wolf Tank Battery	33.70	58.2	15.8	26.0	sandy clay loam	0.98

Table 12. Aliphatic hydrocarbon concentrations (in µg/g wet weight) in soil samples collected near the oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	n-decane n-C10	n-undecane n-C11	n-dodecane n-C12	n-tridecane n-C13	n-tetradecane n-C14
Eriksen	ND	ND	0.0017	ND	ND
Fair 1	ND	0.0038	0.0035	0.0035	0.0072
Fair B-5	ND	0.0006	0.0016	ND	ND
Flora B	ND	0.0016	0.0024	0.0012	0.0017
Sara Sleeper 1	ND	ND	ND	ND	ND
Sara Sleeper 3	ND	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND	ND
Sleeper 1	ND	ND	ND	ND	ND
Sleeper 2	ND	ND	ND	ND	0.0007
Sleeper 2	ND	ND	ND	ND	ND
Sleeper A-1	ND	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND	0.0007
Smith Estate B-2	ND	0.0015	0.0033	0.0056	0.0732
Smith Estate B-3	ND	ND	0.0011	ND	0.0009
Smith Estate B-4	ND	0.0006	0.0009	ND	0.0007
Tank Battery	ND	0.0009	0.0012	ND	0.0014
Wolf A-1	ND	ND	0.0024	0.0016	0.0040
Wolf A-2	ND	0.0039	0.0119	0.0332	0.0771
Wolf A-3	ND	0.0005	0.0018	0.0028	0.0087
Wolf A-4	0.0076	0.0035	0.6860	0.9450	0.1850
Wolf A-5	ND	0.0012	0.0010	0.0008	0.0022
Wolf Tank Battery	ND	ND	0.0043	0.0016	0.0168

ND = Not Detected

Table 12. Continued

Site Name	n-pentadecane n-C15	n-hexadecane n-C16	n-heptadecane n-C17	n-octadecane n-C18	n-nonadecane n-C19
Eriksen	ND	0.0102	0.1750	0.0178	0.0385
Fair 1	0.0096	0.0227	0.0329	0.0180	0.0289
Fair B-5	ND	0.0069	0.0145	0.0048	0.0052
Flora B	0.0007	0.0051	0.0018	0.0007	0.0012
Sara Sleeper 1	0.0191	0.0177	0.1690	0.0216	0.0180
Sara Sleeper 3	ND	ND	ND	0.0027	0.0024
Sara Sleeper 4	ND	ND	ND	0.0016	0.0022
Sleeper 1	ND	0.0041	0.0063	0.0206	0.0246
Sleeper 2	ND	0.0070	ND	0.0021	0.0018
Sleeper A-1	ND	0.0065	0.0194	0.0039	0.0082
Sleeper A-2	ND	0.0040	ND	0.0039	0.0008
Sleeper A-5	ND	ND	ND	ND	0.0008
Sleeper B	ND	ND	0.0209	0.0101	0.0931
Smith Estate B-2	0.0169	0.0337	0.0385	0.0429	0.0710
Smith Estate B-3	0.0024	0.0074	0.0025	0.0022	0.0033
Smith Estate B-4	0.0015	0.0069	0.0029	0.0030	0.0043
Tank Battery	0.0911	0.0094	0.1560	0.0049	0.0039
Wolf A-1	0.0185	0.0309	0.2060	0.0531	0.0586
Wolf A-2	0.1430	0.1800	0.1890	0.1590	0.1770
Wolf A-3	0.0173	0.0411	0.0612	0.0675	0.1120
Wolf A-4	0.0124	0.0733	1.2400	0.0324	0.0276
Wolf A-5	0.0016	0.0106	0.0102	0.0069	0.0106
Wolf Tank Battery	0.0472	0.0819	0.3430	0.1070	0.3680

ND = Not Detected

Table 12. Continued

Site Name	n-eicosane n-C20	n-heneicosane n-C21	n-docosane n-C22	n-tricosane n-C23	n-tetracosane n-C24
Eriksen	0.0218	0.0516	0.0641	0.0572	0.0020
Fair 1	0.0255	0.0118	0.0125	0.0600	0.0171
Fair B-5	0.0041	0.0066	0.0036	0.0088	0.0114
Flora B	0.0019	0.0040	0.0026	0.0152	0.0038
Sara Sleeper 1	0.0095	0.0209	0.0097	0.0937	0.0363
Sara Sleeper 3	0.0010	0.0042	0.0006	0.0061	0.0042
Sara Sleeper 4	0.0032	0.0048	0.0042	0.0075	0.0081
Sleeper 1	0.0274	0.0273	0.0182	0.0162	0.0117
Sleeper 2	0.0027	0.0017	0.0083	0.0071	0.0024
Sleeper A-1	0.0022	0.0048	0.0138	0.0060	0.0097
Sleeper A-2	0.0020	0.0049	0.0006	0.0206	0.0057
Sleeper A-5	0.0019	ND	0.0045	0.0118	0.0103
Sleeper B	0.0103	0.0279	0.0059	0.0360	0.0159
Smith Estate B-2	0.0717	0.0694	0.0666	0.0855	0.0525
Smith Estate B-3	0.0044	0.0072	0.0062	0.0155	0.0079
Smith Estate B-4	0.0053	0.0070	0.0053	0.0093	0.0048
Tank Battery	0.0049	0.0039	0.0031	0.0077	0.0096
Wolf A-1	0.0426	0.0554	0.0296	0.1070	0.0264
Wolf A-2	0.1700	0.1250	0.0912	0.1100	0.0559
Wolf A-3	0.0998	0.0874	0.0774	0.0969	0.0655
Wolf A-4	0.0206	0.1210	0.0172	0.1290	0.0528
Wolf A-5	0.0063	0.0113	0.0060	0.0151	0.0032
Wolf Tank Battery	0.1140	0.1490	0.0914	0.2310	0.0857

ND = Not Detected

Table 12. Continued

Site Name	n-pentacosane n-C25	n-hexacosane n-C26	n-heptacosane n-C27	n-octacosane n-C28	n-nonacosane n-C29
Eriksen	0.1530	0.0107	0.2600	0.1010	0.8190
Fair 1	0.0757	0.0141	0.1440	0.0166	0.2040
Fair B-5	0.0768	0.0207	0.0968	0.0359	0.1870
Flora B	0.0269	0.0116	0.0809	0.0081	0.1240
Sara Sleeper 1	0.3040	0.0454	0.3020	0.0507	0.3240
Sara Sleeper 3	0.0216	0.0065	0.0430	0.0164	0.1240
Sara Sleeper 4	0.0292	0.0131	0.0637	0.0108	0.0832
Sleeper 1	0.0348	0.0210	0.1360	0.0635	0.4680
Sleeper 2	0.0133	0.0049	0.0034	0.0122	0.2880
Sleeper A-1	0.1910	0.0116	0.1470	0.0437	0.3950
Sleeper A-2	0.0671	0.0125	0.1110	0.0297	0.2140
Sleeper A-5	0.0277	0.0073	0.0848	ND	0.1810
Sleeper B	0.1100	0.0583	0.3490	0.1060	1.0200
Smith Estate B-2	0.0877	0.0449	0.1170	0.0119	0.2560
Smith Estate B-3	0.0577	0.0243	0.1180	0.0350	0.4810
Smith Estate B-4	0.0189	0.0039	0.0429	0.0144	0.1330
Tank Battery	0.0599	0.0212	0.0830	0.0316	0.1870
Wolf A-1	0.1880	0.0151	0.3140	0.0491	0.3660
Wolf A-2	0.1050	0.0483	0.1020	0.0247	0.0712
Wolf A-3	0.1120	0.0349	0.2240	0.0447	0.2320
Wolf A-4	0.1090	0.3440	0.0488	0.2190	0.0501
Wolf A-5	0.0317	0.0033	0.0650	0.0094	0.1060
Wolf Tank Battery	0.5260	0.0962	0.9900	0.1570	1.3700

ND = Not Detected

Table 12. Continued

Site Name	n-triacontane n-C30	n-hentriacontane n-C31	n-dotriacontane n-C32	n-tritriacontane n-C33
Eriksen	0.0065	1.5400	0.4830	0.9780
Fair 1	0.0613	0.3940	0.0203	0.2550
Fair B-5	0.0608	0.2460	0.0417	0.1260
Flora B	0.0322	0.2380	0.0174	0.1970
Sara Sleeper 1	0.0340	0.3560	0.0430	0.2600
Sara Sleeper 3	0.0210	0.1370	0.0112	0.0477
Sara Sleeper 4	0.0156	0.0995	0.0118	0.0570
Sleeper 1	0.0434	0.3900	0.0285	0.2180
Sleeper 2	0.0020	0.3390	0.0021	0.3130
Sleeper A-1	0.0011	0.4070	0.0311	0.4240
Sleeper A-2	0.0399	0.2850	0.0227	0.1700
Sleeper A-5	0.0410	0.2760	0.0531	0.2650
Sleeper B	0.1050	1.7500	0.0932	0.8060
Smith Estate B-2	0.0718	0.3850	0.0045	0.1910
Smith Estate B-3	0.0335	0.2280	0.0079	0.0756
Smith Estate B-4	0.0210	0.1600	0.0074	0.0590
Tank Battery	0.0522	0.4760	0.0284	0.2220
Wolf A-1	0.0403	0.3020	0.0208	0.2060
Wolf A-2	0.0468	0.1390	0.0263	0.1150
Wolf A-3	0.0829	0.2740	0.0380	0.1950
Wolf A-4	0.0829	0.0378	0.1290	0.1630
Wolf A-5	0.0153	0.0833	0.0095	0.0655
Wolf Tank Battery	0.0952	0.7370	0.1280	0.3810

ND = Not Detected

Table 12. Continued

Site Name	n-tetratriacontane n-C34	phytane	pristane	UCM
Eriksen	0.0052	0.0745	0.0674	296.0
Fair 1	0.0024	0.0239	0.0210	213.0
Fair B-5	0.0011	0.0032	0.0095	22.0
Flora B	0.0021	ND	ND	96.0
Sara Sleeper 1	0.0055	0.0225	0.0132	26.8
Sara Sleeper 3	ND	0.0013	0.0173	ND
Sara Sleeper 4	0.0058	0.0014	0.0081	0.8
Sleeper 1	ND	0.0508	0.0413	24.8
Sleeper 2	0.0046	0.0185	0.0173	577.0
Sleeper A-1	0.0026	0.0104	0.0168	203.0
Sleeper A-2	0.0076	0.0031	0.0460	ND
Sleeper A-5	0.0010	ND	ND	84.5
Sleeper B	0.0250	0.0280	0.0069	5.9
Smith Estate B-2	0.0008	0.0665	0.0571	154.0
Smith Estate B-3	0.0027	0.0032	0.0035	1.5
Smith Estate B-4	0.0095	0.0036	0.0036	ND
Tank Battery	0.0091	0.0018	0.0021	14.7
Wolf A-1	0.0346	0.0848	0.0513	71.6
Wolf A-2	0.0059	0.1410	0.1440	155.0
Wolf A-3	0.0570	0.0639	0.0458	138.0
Wolf A-4	0.1170	0.0204	0.0562	10010.0
Wolf A-5	0.0096	0.0074	0.0051	31.0
Wolf Tank Battery	0.0389	0.0907	0.0973	90.2

ND = Not Detected
UCM = Unresolved Complex Mixture

Table 13. Indices used to determine petrogenic or biogenic origin of aliphatic hydrocarbons in soil samples collected near oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	C17/Pri+	C18/Phy#	Odd/Even Ratio*	Pri/Phy Ratio+#	C16 Ratio*◊	LMW/ HMW*	CPI*
Eriksen	2.60	0.24	5.63	0.90	5.30	0.058	9.85
Fair 1	1.57	0.75	5.53	0.88	1.55	0.121	6.41
Fair B-5	1.53	1.51	3.99	3.00	1.12	0.041	3.70
Flora B	NC	NC	7.73	NC	1.19	0.024	6.83
Sara Sleeper 1	12.80	0.96	6.83	0.59	2.44	0.135	6.92
Sara Sleeper 3	0.00	2.05	6.07	13.41	NC	0.014	5.54
Sara Sleeper 4	0.00	1.17	4.68	5.81	NC	0.017	5.84
Sleeper 1	0.15	0.41	5.54	0.81	1.56	0.056	6.31
Sleeper 2	0.00	0.11	19.72	0.94	1.67	0.014	18.63
Sleeper A-1	1.15	0.38	12.70	1.62	2.13	0.024	10.83
Sleeper A-2	0.00	1.24	6.79	14.65	2.88	0.011	5.81
Sleeper A-5	NC	NC	7.12	NC	NC	0.003	11.01
Sleeper B	3.03	0.36	9.79	0.25	NC	0.030	7.30
Smith Estate B-2	0.67	0.65	2.77	0.86	1.83	0.248	5.31
Smith Estate B-3	0.71	0.69	7.42	1.09	1.49	0.022	9.37
Smith Estate B-4	0.81	0.83	5.29	1.00	1.89	0.053	6.55
Tank Battery	74.29	2.72	7.30	1.17	2.43	0.229	3.95
Wolf A-1	4.02	0.63	5.23	0.60	3.26	0.238	8.85
Wolf A-2	1.31	1.13	1.46	1.02	2.24	1.073	2.40
Wolf A-3	1.34	1.06	2.28	0.72	3.36	0.254	4.40
Wolf A-4	22.06	1.59	1.47	2.75	6.33	1.995	0.23
Wolf A-5	2.00	0.93	4.83	0.69	1.38	0.118	9.14
Wolf Tank Battery	3.53	1.18	5.06	1.07	6.60	0.213	9.34

NC = Not Calculated
CPI = Carbon Preference Index
LMW/HMW = Low Molecular Weight/High Molecular Weight
* Any values from Table10 that are "ND" were calculated as "0" in the formulas.
\+ Pristane concentration is "ND" for any ratio that is "NC"
\# Phytane concentration is "ND" for any ratio that is "NC"
◊ n-C16 concentration is "ND" for any ratio that is "NC"

Table 14. Aliphatic hydrocarbon concentrations (in µg/g wet weight) of fish samples collected on Quivira National Wildlife Refuge, 1996.

Sample	% Lipid	% Moisture	n-decane n-C10	n-undecane n-C11	n-dodecane n-C12	n-tridecane n-C13	n-tetradecane n-C14
Carp 1	5.02	74.8	ND	0.0234	0.0347	0.0443	0.0349
Carp 2	2.84	76.4	ND	0.0200	0.0279	0.0328	0.0187
Carp 3	2.74	73.0	ND	0.0096	0.0164	0.0229	0.0119
Carp 4	3.24	75.2	ND	0.0646	0.0391	0.3030	0.0212
Carp 5	1.65	77.7	ND	0.0279	0.0299	0.0348	0.0213
Forage Fish 1	5.04	75.8	0.0227	0.0198	0.0193	0.0392	0.0160
Forage Fish 2	1.08	79.7	0.0297	0.0286	0.0343	0.0460	0.0250
Forage Fish 3	2.08	80.2	0.0076	0.0298	0.0298	0.0487	0.0237
Forage Fish 4	2.47	77.6	ND	0.0319	0.0442	0.0745	0.0340
Forage Fish 5	2.94	81.2	0.0377	0.0222	0.0276	0.0525	0.0364
Forage Fish 6	2.94	77.0	0.0181	0.0196	0.0320	0.0599	0.0464
Forage Fish 7	2.72	78.0	0.0676	0.0201	0.0337	0.0482	0.0440

Sample	n-pentadecane n-C15	n-hexadecane n-C16	n-heptadecane n-C17	n-octadecane n-C18	n-nonadecane n-C19	n-eicosane n-C20
Carp 1	0.2280	0.1210	1.5500	0.6120	1.7000	0.3040
Carp 2	0.3240	0.1180	1.7200	0.2930	2.1700	0.5070
Carp 3	0.0625	0.0733	1.7100	0.6890	1.1600	1.4000
Carp 4	0.1290	0.1560	4.2300	0.6500	2.5100	0.6010
Carp 5	0.1650	0.1010	2.8300	0.1970	1.4500	0.1630
*Forage Fish 1	0.3490	0.2970	7.1900	0.8240	2.0500	1.2300
*Forage Fish 2	0.0592	0.0576	0.2560	0.0364	0.0616	0.0267
*Forage Fish 3	0.3010	0.1100	3.0400	0.1710	0.1160	0.2980
*Forage Fish 4	0.0396	0.0561	0.1300	0.4310	0.1420	0.8410
*Forage Fish 5	0.4510	0.1450	2.2200	0.2120	0.0902	0.2710
*Forage Fish 6	0.7520	0.1690	4.3500	0.1400	0.3270	0.0912
*Forage Fish 7	0.4700	0.1480	4.4900	0.1930	0.2340	0.0512

ND = Not Detected

*Forage fish were composed of composite samples of unidentified species.

Forage Fish 8 was not analyzed for aliphatic hydrocarbons due to small sample size.

Table 14. Continued.

Sample	n-heneicosane n-C21	n-docosane n-C22	n-tricosane n-C23	n-tetracosane n-C24	n-pentacosane n-C25	n-hexacosane n-C26
Carp 1	0.1960	0.0694	0.0467	0.1390	0.0274	0.0199
Carp 2	1.9900	0.2230	0.2150	0.0116	0.0057	0.0040
Carp 3	0.4020	0.1850	0.0250	0.3430	0.3930	0.0830
Carp 4	0.3930	0.1200	0.5720	0.0499	0.9050	0.0715
Carp 5	0.7970	0.0186	0.1510	0.0133	0.0881	0.0096
*Forage Fish 1	0.7360	0.1700	0.2780	0.0144	0.0352	0.0144
*Forage Fish 2	0.0358	0.0318	0.0613	0.0195	0.0599	0.0334
*Forage Fish 3	0.4150	0.0510	0.0912	0.0111	0.0499	0.0242
*Forage Fish 4	1.5300	ND	0.2620	0.0145	0.0138	0.0281
*Forage Fish 5	0.4680	ND	0.0810	0.0139	0.0046	0.0244
*Forage Fish 6	0.1200	0.0373	0.0382	0.0181	0.0567	0.0274
*Forage Fish 7	0.1750	0.0312	0.0481	0.0304	0.0764	0.0374

Sample	n-heptacosane n-C27	n-octacosane n-C28	n-nonacosane n-C29	n-triacontane n-C30	n-hentriacontane n-C31
Carp 1	0.0076	7.20	3.82	0.0064	0.0077
Carp 2	0.0912	17.60	10.30	0.0076	0.0364
Carp 3	0.1610	13.10	8.20	0.0700	ND
Carp 4	0.6380	7.43	4.88	0.0144	0.1440
Carp 5	0.0153	12.50	7.89	0.0034	0.0074
*Forage Fish 1	0.0408	12.70	8.76	0.0034	0.0193
*Forage Fish 2	0.0709	10.70	6.97	0.0055	0.0523
*Forage Fish 3	0.0657	15.10	10.30	0.0099	0.0140
*Forage Fish 4	0.0589	10.30	6.88	0.0053	0.0072
*Forage Fish 5	0.0492	13.50	9.19	0.0365	0.0601
*Forage Fish 6	0.0134	11.50	7.96	0.0165	0.0719
*Forage Fish 7	0.0242	5.40	3.43	0.0544	0.0351

ND = Not Detected

*Forage fish were composed of composite samples of unidentified species.

Forage Fish 8 was not analyzed for aliphatic hydrocarbons due to small sample size.

Table 14. Continued.

Sample	n-dotriacontane n-C32	n-tritriacontane n-C33	n-tetratriacontane n-C34	Phytane	Pristane	UCM
Carp 1	0.2470	0.0525	ND	1.0800	0.0411	83.1
Carp 2	0.0040	0.0142	0.0030	0.2770	0.0165	70.6
Carp 3	0.0075	0.1350	ND	0.1900	0.0205	41.6
Carp 4	0.1600	0.0029	0.0035	0.1660	0.0076	53.3
Carp 5	0.0042	0.1540	ND	0.0748	0.0080	19.4
*Forage Fish 1	0.0279	0.1420	0.0041	0.1800	0.0435	25.8
*Forage Fish 2	0.0112	0.0044	ND	0.1820	0.0132	11.0
*Forage Fish 3	0.0106	ND	ND	0.0634	0.0079	5.8
*Forage Fish 4	ND	0.0042	ND	0.2110	0.0551	7.6
*Forage Fish 5	ND	ND	ND	0.4550	0.0278	6.4
*Forage Fish 6	ND	0.0086	0.0033	0.5860	0.0280	3.6
*Forage Fish 7	ND	0.0069	0.0043	0.2450	0.0187	4.9

ND = Not Detected
UCM = Unresolved complex mixture
*Forage fish were composed of composite samples of unidentified species.
Forage Fish 8 was not analyzed for aliphatic hydrocarbons due to small sample size.

Table 15. Indices used to determine petrogenic or biogenic origin of aliphatic hydrocarbons in fish samples collected on Quivira National Wildlife Refuge, 1996.

Sample	C17/Pristane Ratio	C18/Phytane Ratio	Odd/Even Ratio*	Pri/Phy	C16 Ratio*	LMW/ HMW*	CPI*
Carp 1	37.71	0.57	0.88	0.038	16.492	0.395	0.53
Carp 2	104.24	1.06	0.90	0.060	35.760	0.172	0.59
Carp 3	83.41	3.63	0.77	0.108	28.260	0.224	0.63
Carp 4	556.58	3.92	1.59	0.046	24.107	0.566	0.74
Carp 5	353.75	2.63	1.04	0.107	26.672	0.234	0.63
Forage Fish 1	165.29	4.58	1.28	0.242	35.012	0.529	0.69
Forage Fish 2	19.39	0.20	0.70	0.073	18.717	0.037	0.66
Forage Fish 3	384.81	2.70	0.91	0.125	30.318	0.160	0.69
Forage Fish 4	2.36	2.04	0.78	0.261	20.928	0.096	0.67
Forage Fish 5	79.86	0.47	0.89	0.061	26.993	0.152	0.68
Forage Fish 6	155.36	0.24	1.14	0.048	25.893	0.302	0.69
Forage Fish 7	240.11	0.79	1.49	0.076	15.178	0.621	0.63

*Any values from Table 11 that are "ND" were calculated as "0" in the formulas.
Pri/Phy = Pristane/Phytane
LWM/HWM = Low Molecular Weight/High Molecular Weight
CPI = Carbon Preference Index

Table 16. Polycyclic aromatic hydrocarbon (PAH) concentrations (in µg/g wet weight) in soil collected near oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	1,2,5,6-dibenzanthrace	1,2-benzanthracene	1,6,7-Trimethyl-naphthalene	1-methylnaphthalene
Eriksen	0.02480	0.07540	0.00085	0.00230
Fair 1	0.00314	0.02400	0.00061	0.00129
Fair B-5	ND	ND	0.00068	0.00152
Flora B	0.00079	ND	ND	0.00059
Sara Sleeper 1	ND	ND	ND	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	ND	ND	ND
Sleeper 2	ND	ND	ND	ND
Sleeper A-1	ND	ND	ND	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	ND	ND	ND	0.00089
Smith Estate B-3	ND	ND	ND	ND
Smith Estate B-4	ND	0.00092	ND	ND
Tank Battery	ND	ND	ND	ND
Wolf A-1	ND	0.00288	ND	ND
Wolf A-2	ND	ND	ND	0.00095
Wolf A-3	0.00066	ND	ND	ND
Wolf A-4	0.00886	0.01990	0.00133	0.00477
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	ND	0.00066	0.00078	0.00094

ND = Not Detected

Table 16. Continued.

Site Name	1-methylphenanthrene	2,6-dimethylnaphthalene	2-methylnaphthalene	acenaphthalene
Eriksen	0.00988	0.00160	0.00394	0.06260
Fair 1	0.00262	0.00083	0.00174	ND
Fair B-5	0.00081	0.00117	0.00162	ND
Flora B	0.00076	ND	0.00084	ND
Sara Sleeper 1	ND	ND	0.00054	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	0.00089	ND	ND	ND
Sleeper 2	0.00200	ND	0.00055	ND
Sleeper A-1	ND	ND	0.00059	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	0.00213	ND	0.00112	ND
Smith Estate B-3	ND	ND	0.00054	ND
Smith Estate B-4	0.00051	ND	ND	ND
Tank Battery	ND	ND	0.00074	ND
Wolf A-1	0.00084	ND	0.00054	ND
Wolf A-2	0.00124	ND	0.00119	ND
Wolf A-3	0.00163	ND	0.00075	ND
Wolf A-4	0.00518	0.00401	0.00519	0.02780
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	0.00134	0.00079	0.00114	ND

ND = Not Detected

Table 16. Continued.

Site Name	acenaphthene	anthracene	benzo(a)pyrene	benzo(b)fluoranthene
Eriksen	0.00126	0.09100	0.03790	0.18100
Fair 1	0.00078	0.00333	0.02120	0.02700
Fair B-5	ND	ND	ND	0.00061
Flora B	ND	ND	ND	ND
Sara Sleeper 1	ND	ND	0.00058	0.00062
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	0.00061	0.00062	ND
Sleeper 2	ND	0.00120	ND	ND
Sleeper A-1	ND	ND	ND	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	0.00123	ND
Smith Estate B-2	ND	0.00114	ND	0.00058
Smith Estate B-3	ND	ND	0.00067	ND
Smith Estate B-4	ND	ND	ND	ND
Tank Battery	ND	ND	ND	0.00084
Wolf A-1	ND	ND	ND	0.00070
Wolf A-2	0.00122	0.00058	ND	ND
Wolf A-3	ND	ND	ND	0.00053
Wolf A-4	0.04560	0.03870	ND	0.02500
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	0.00069	ND	0.00140	0.00079

ND = Not Detected

Table 16. Continued

Site Name	benzo(e)pyrene	benzo(g,h,i)perylene	benzo(k)fluoranthene	biphenyl
Eriksen	0.08540	0.09670	0.04900	0.00087
Fair 1	0.01930	0.02810	0.00515	ND
Fair B-5	0.00063	0.00097	ND	ND
Flora B	0.00902	0.00212	ND	ND
Sara Sleeper 1	ND	0.00052	ND	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	ND	ND	ND
Sleeper 2	ND	ND	ND	ND
Sleeper A-1	0.00103	0.00089	ND	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	0.00241	0.00197	ND	ND
Smith Estate B-3	ND	ND	ND	ND
Smith Estate B-4	ND	ND	ND	ND
Tank Battery	0.00058	ND	ND	ND
Wolf A-1	0.00075	0.00059	0.00081	ND
Wolf A-2	0.00070	0.00073	ND	ND
Wolf A-3	0.00182	0.00134	ND	ND
Wolf A-4	ND	0.00626	0.00310	0.00768
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	0.00096	0.00082	ND	ND

ND = Not Detected

Table 16. Continued.

Site Name	C1-chrysenes	C1-dibenzothiophenes	C1-Fluoranthenes & Pyrenes	C1-fluorenes
Eriksen	0.07230	0.00198	0.08800	0.00285
Fair 1	0.00899	ND	0.02210	ND
Fair B-5	0.00147	0.00098	0.00251	ND
Flora B	ND	ND	ND	ND
Sara Sleeper 1	ND	ND	ND	0.00059
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	0.00106	ND	0.00195	0.00056
Sleeper 2	ND	ND	ND	0.00061
Sleeper A-1	ND	ND	ND	0.00064
Sleeper A-2	ND	ND	ND	0.00050
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	ND	ND	ND	ND
Smith Estate B-3	ND	ND	ND	ND
Smith Estate B-4	ND	ND	ND	ND
Tank Battery	ND	ND	ND	ND
Wolf A-1	0.00292	0.00091	0.00142	0.00060
Wolf A-2	ND	ND	ND	ND
Wolf A-3	ND	ND	ND	ND
Wolf A-4	ND	0.07730	ND	ND
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	0.00157	0.00201	ND	0.00103

ND = Not Detected

Table 16. Continued.

Site Name	C1-naphthalenes	C1-Phenanthrenes & Anthracenes	C2-chrysenes	C2-dibenzothiophenes
Eriksen	0.00624	0.03160	0.04180	0.00528
Fair 1	0.00303	ND	0.01940	ND
Fair B-5	0.00314	0.00354	0.00351	0.00198
Flora B	0.00143	ND	ND	ND
Sara Sleeper 1	0.00087	0.00108	0.00162	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	0.00055	0.00053	ND	ND
Sleeper 1	0.00079	0.00199	0.00257	ND
Sleeper 2	0.00093	0.00442	ND	ND
Sleeper A-1	0.00100	ND	0.00571	ND
Sleeper A-2	0.00053	0.00058	ND	ND
Sleeper A-5	0.00061	ND	ND	ND
Sleeper B	ND	ND	0.00071	ND
Smith Estate B-2	0.00201	ND	ND	ND
Smith Estate B-3	0.00083	ND	ND	ND
Smith Estate B-4	0.00066	0.00107	ND	ND
Tank Battery	0.00123	0.00110	ND	ND
Wolf A-1	0.00093	0.00287	0.00722	0.00412
Wolf A-2	0.00214	ND	ND	ND
Wolf A-3	0.00124	ND	ND	ND
Wolf A-4	0.00996	ND	ND	0.20400
Wolf A-5	0.00055	ND	ND	ND
Wolf Tank Battery	0.00208	0.00478	0.00573	0.00292

ND = Not Detected

Table 16. Continued.

Site Name	C2-fluorenes	C2-naphthalenes	C2-Phenanthrenes & Anthracenes	C3-chrysenes
Eriksen	ND	0.00553	0.04360	0.00731
Fair 1	ND	0.00281	ND	ND
Fair B-5	ND	0.00343	0.00493	0.00084
Flora B	ND	0.00086	ND	ND
Sara Sleeper 1	ND	0.00078	0.00147	ND
Sara Sleeper 3	ND	0.00052	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	ND	0.00409	ND
Sleeper 2	ND	0.00121	0.00627	ND
Sleeper A-1	ND	0.00101	0.00472	0.00213
Sleeper A-2	ND	ND	0.00083	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	0.00059	0.00059	ND
Smith Estate B-2	ND	0.00170	ND	ND
Smith Estate B-3	ND	0.00054	ND	ND
Smith Estate B-4	ND	ND	0.00197	ND
Tank Battery	ND	0.00065	ND	ND
Wolf A-1	0.00182	0.00068	0.00922	0.00071
Wolf A-2	ND	0.00126	ND	ND
Wolf A-3	ND	0.00096	ND	ND
Wolf A-4	ND	ND	ND	ND
Wolf A-5	ND	0.00062	ND	ND
Wolf Tank Battery	0.00341	0.00296	0.00930	ND

ND = Not Detected

Table 16. Continued.

Site Name	C3-dibenzothiophenes	C3-fluorenes	C3-naphthalenes	C3-Phenanthrenes & Anthracenes
Eriksen	0.00766	ND	0.00621	0.04400
Fair 1	ND	ND	0.00467	ND
Fair B-5	0.00194	ND	0.00311	0.00563
Flora B	ND	ND	0.00276	ND
Sara Sleeper 1	ND	ND	ND	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	ND	0.00069	0.00246
Sleeper 2	ND	ND	0.00084	ND
Sleeper A-1	ND	ND	0.00156	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	0.00068
Smith Estate B-2	ND	ND	0.00308	ND
Smith Estate B-3	ND	ND	0.00103	ND
Smith Estate B-4	ND	ND	0.00071	0.00119
Tank Battery	ND	ND	0.00101	ND
Wolf A-1	0.00738	0.01120	0.00120	0.02190
Wolf A-2	ND	ND	0.00317	ND
Wolf A-3	ND	ND	0.00316	ND
Wolf A-4	0.24400	ND	ND	ND
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	0.00319	ND	0.00553	0.00594

ND = Not Detected

Table 16. Continued.

Site Name	C4-chrysenes	C4-naphthalenes	C4-Phenanthrenes & Anthracenes	chrysene
Eriksen	0.01690	0.00866	0.01970	0.19300
Fair 1	ND	0.00941	ND	0.02600
Fair B-5	0.00086	0.00362	0.00234	0.00083
Flora B	ND	0.00534	ND	0.00467
Sara Sleeper 1	ND	ND	ND	0.00051
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	0.00057
Sleeper 1	ND	ND	ND	0.00071
Sleeper 2	ND	ND	ND	0.00096
Sleeper A-1	0.00471	ND	ND	0.00152
Sleeper A-2	ND	ND	ND	0.00095
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	ND	0.00671	ND	0.00161
Smith Estate B-3	ND	0.00165	ND	ND
Smith Estate B-4	ND	0.00103	ND	0.00051
Tank Battery	ND	0.00128	ND	0.00102
Wolf A-1	ND	0.00300	0.01130	0.00303
Wolf A-2	ND	0.00667	ND	ND
Wolf A-3	ND	0.00954	ND	0.00055
Wolf A-4	ND	ND	ND	0.00652
Wolf A-5	ND	0.00156	ND	ND
Wolf Tank Battery	ND	0.00478	ND	0.00197

Table 16. Continued.

Site Name	dibenzothiophene	fluoranthene	fluorene	indeno(1,2,3-cd)pyrene
Eriksen	0.00103	0.16400	0.00164	0.09320
Fair 1	0.00099	0.03770	0.00056	0.01130
Fair B-5	ND	0.00078	ND	ND
Flora B	ND	0.00053	ND	ND
Sara Sleeper 1	ND	0.00057	ND	ND
Sara Sleeper 3	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND
Sleeper 1	ND	ND	ND	ND
Sleeper 2	ND	0.00090	ND	ND
Sleeper A-1	ND	0.00057	ND	ND
Sleeper A-2	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND
Smith Estate B-2	ND	0.00080	ND	0.00056
Smith Estate B-3	ND	0.00050	ND	ND
Smith Estate B-4	ND	ND	ND	ND
Tank Battery	ND	0.00117	ND	ND
Wolf A-1	ND	0.00067	ND	ND
Wolf A-2	ND	0.00061	ND	ND
Wolf A-3	ND	0.00110	ND	ND
Wolf A-4	0.00189	0.00067	0.00497	0.00449
Wolf A-5	ND	ND	ND	ND
Wolf Tank Battery	ND	0.00098	ND	ND

ND = Not Detected

Table 16. Continued.

Site Name	naphthalene	perylene	phenanthrene	pyrene
Eriksen	0.00597	0.02860	0.02370	0.16700
Fair 1	0.00168	0.04420	0.01470	0.03150
Fair B-5	0.00209	ND	0.00167	0.00086
Flora B	0.00217	ND	0.00060	ND
Sara Sleeper 1	0.00145	0.00215	0.00053	ND
Sara Sleeper 3	0.00078	ND	ND	ND
Sara Sleeper 4	0.00127	ND	ND	ND
Sleeper 1	0.00168	ND	ND	0.00064
Sleeper 2	0.00102	ND	0.00070	0.00075
Sleeper A-1	0.00160	ND	ND	ND
Sleeper A-2	0.00136	ND	ND	ND
Sleeper A-5	0.00113	ND	ND	ND
Sleeper B	0.00109	ND	0.00052	ND
Smith Estate B-2	0.00147	0.01430	0.00134	0.00083
Smith Estate B-3	0.00106	ND	ND	ND
Smith Estate B-4	0.00086	ND	ND	ND
Tank Battery	0.00244	ND	0.00088	0.00101
Wolf A-1	0.00108	ND	0.00076	0.00082
Wolf A-2	0.00215	ND	0.00087	ND
Wolf A-3	0.00114	ND	0.00133	0.00089
Wolf A-4	0.00374	0.04290	0.00992	0.01130
Wolf A-5	0.00089	ND	ND	ND
Wolf Tank Battery	0.00166	ND	0.00180	0.00089

ND = Not Detected

Table 17. Organochlorine concentrations (in µg/g wet weight) in soil samples collected near oil production facilities on Quivira National Wildlife Refuge, 1996.

Site Name	HCB	endosulfan II	alpha BHC	beta BHC	delta BHC	gamma BHC
Eriksen	0.0001	ND	ND	ND	ND	ND
Fair 1	ND	ND	ND	0.0001	ND	ND
Fair B-5	ND	ND	ND	ND	ND	ND
Flora B	ND	ND	ND	0.0001	ND	ND
Sara Sleeper 1	ND	ND	ND	0.0001	ND	ND
Sara Sleeper 3	ND	ND	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	0.0002	ND	0.0001
Sleeper 1	ND	ND	ND	0.0002	ND	0.0001
Sleeper 2	0.0001	ND	ND	0.0001	ND	ND
Sleeper A-1	ND	ND	ND	ND	ND	ND
Sleeper A-2	ND	ND	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND	ND	ND
Sleeper B	ND	ND	ND	0.0002	ND	0.0001
Smith Estate B-2	ND	ND	ND	0.0001	ND	ND
Smith Estate B-3	ND	ND	ND	ND	ND	ND
Smith Estate B-4	ND	ND	ND	0.0001	ND	0.0001
Tank Battery	ND	ND	ND	0.0001	ND	ND
Wolf A-1	ND	ND	ND	ND	ND	ND
Wolf A-2	ND	ND	ND	ND	ND	ND
Wolf A-3	ND	ND	ND	ND	ND	ND
Wolf A-4	ND	ND	ND	ND	ND	ND
Wolf A-5	ND	ND	ND	ND	ND	ND
Wolf Tank Battery	ND	ND	ND	0.0001	ND	ND

ND = Not Detected

Table 17. Continued.

Site Name	alpha chlordane	gamma chlordane	cis-nonachlor	trans-nonachlor	oxychlordane
Eriksen	ND	0.0001	ND	0.0001	ND
Fair 1	ND	ND	ND	0.0001	ND
Fair B-5	ND	ND	ND	ND	ND
Flora B	ND	ND	ND	ND	ND
Sara Sleeper 1	0.0001	0.0001	ND	ND	0.0001
Sara Sleeper 3	ND	ND	ND	ND	ND
Sara Sleeper 4	ND	ND	ND	ND	ND
Sleeper 1	ND	ND	ND	ND	ND
Sleeper 2	ND	ND	ND	ND	ND
Sleeper A-1	0.0011	0.0014	0.0006	0.0011	ND
Sleeper A-2	ND	ND	ND	ND	ND
Sleeper A-5	ND	ND	ND	ND	ND
Sleeper B	ND	ND	ND	ND	ND
Smith Estate B-2	0.0001	0.0001	ND	0.0001	ND
Smith Estate B-3	ND	ND	ND	ND	ND
Smith Estate B-4	ND	ND	ND	ND	ND
Tank Battery	ND	ND	ND	ND	ND
Wolf A-1	ND	ND	ND	ND	ND
Wolf A-2	ND	ND	ND	ND	ND
Wolf A-3	0.0001	0.0001	ND	0.0001	ND
Wolf A-4	ND	ND	ND	ND	ND
Wolf A-5	ND	ND	ND	0.0001	ND
Wolf Tank Battery	ND	0.0001	ND	ND	ND

ND = Not Detected

Table 17. Continued.

Site Name	Heptachlor	heptachlor epoxide	Aldrin	dieldrin	endrin	mirex	PCB-Total
Eriksen	ND	ND	ND	ND	ND	ND	0.0015
Fair 1	ND	ND	ND	0.0001	ND	ND	0.0016
Fair B-5	ND	ND	ND	ND	ND	ND	0.0017
Flora B	ND	ND	ND	0.0003	ND	ND	0.0023
Sara Sleeper 1	ND	ND	0.0001	ND	ND	ND	0.0029
Sara Sleeper 3	ND	ND	ND	ND	ND	ND	0.0005
Sara Sleeper 4	ND	ND	ND	ND	ND	ND	0.0008
Sleeper 1	ND	ND	ND	ND	ND	ND	0.001
Sleeper 2	ND	ND	ND	ND	0.0001	ND	0.0054
Sleeper A-1	ND	ND	ND	ND	ND	ND	0.0029
Sleeper A-2	ND	ND	ND	ND	ND	ND	0.001
Sleeper A-5	ND	ND	ND	ND	0.0001	ND	0.0018
Sleeper B	ND	ND	ND	ND	ND	ND	0.0024
Smith Estate B-2	ND	ND	ND	0.0003	ND	ND	0.0017
Smith Estate B-3	ND	ND	ND	0.0001	ND	ND	0.0013
Smith Estate B-4	ND	ND	ND	0.0001	ND	ND	0.0015
Tank Battery	ND	ND	ND	ND	ND	ND	0.0012
Wolf A-1	ND	ND	ND	ND	0.0001	ND	0.0016
Wolf A-2	ND	ND	ND	ND	ND	ND	0.0016
Wolf A-3	ND	ND	ND	0.0002	0.0001	ND	0.0015
Wolf A-4	ND	0.0002	ND	ND	ND	0.0002	0.0054
Wolf A-5	ND	ND	ND	0.0001	ND	ND	ND
Wolf Tank Battery	ND	ND	ND	ND	ND	ND	0.0023

ND = Not Detected

Table 17. Continued.

Site Name	o,p'-DDD	o,p'-DDE	o,p'-DDT	"p,p'-DDD"	p,p'-DDE	p,p'-DDT	Total DDT
Eriksen	0.0005	ND	0.0002	0.0005	0.0003	0.0005	0.0020
Fair 1	ND	ND	ND	ND	ND	0.0001	0.0001
Fair B-5	ND	ND	ND	ND	ND	ND	NC
Flora B	ND	ND	ND	ND	ND	0.0001	0.0001
Sara Sleeper 1	0.0001	ND	ND	0.0002	0.0003	ND	0.0006
Sara Sleeper 3	ND	ND	ND	ND	ND	ND	NC
Sara Sleeper 4	ND	ND	ND	ND	ND	ND	NC
Sleeper 1	ND	ND	ND	ND	ND	ND	NC
Sleeper 2	ND	ND	ND	ND	ND	ND	NC
Sleeper A-1	ND	ND	ND	ND	ND	ND	NC
Sleeper A-2	ND	ND	ND	ND	ND	ND	NC
Sleeper A-5	ND	ND	ND	ND	ND	ND	NC
Sleeper B	ND	ND	ND	ND	0.0001	ND	0.0001
Smith Estate B-2	ND	ND	ND	ND	ND	0.0001	0.0001
Smith Estate B-3	ND	ND	ND	ND	0.0001	0.0001	0.0002
Smith Estate B-4	ND	ND	ND	ND	ND	0.0001	0.0001
Tank Battery	ND	ND	ND	ND	ND	0.0001	0.0001
Wolf A-1	ND	ND	ND	ND	0.0001	0.0001	0.0002
Wolf A-2	ND	ND	ND	ND	ND	0.0001	0.0001
Wolf A-3	ND	ND	ND	ND	0.0001	0.0001	0.0002
Wolf A-4	ND	ND	ND	ND	ND	ND	NC
Wolf A-5	ND	ND	ND	ND	ND	ND	NC
Wolf Tank Battery	ND	ND	ND	ND	0.0001	ND	0.0001

ND = Not Detected
NC = Not Calculable

Table 18. Organochlorine concentrations (in µg/g wet weight) in invertebrates collected on Quivira National Wildlife Refuge, 1996.

Sample	HCB	endosulfan II	alpha BHC	beta BHC	delta BHC	gamma BHC
Insect 1	ND	ND	ND	ND	ND	ND
Insect 2	ND	ND	ND	ND	ND	ND
Insect 3	ND	ND	ND	ND	ND	ND
Insect 4	ND	ND	ND	ND	ND	ND
Insect 5	ND	ND	ND	ND	ND	ND
Insect 6	ND	ND	ND	ND	ND	ND
Insect 7	ND	ND	ND	ND	ND	ND

Sample	alpha chlordane	gamma chlordane	cis-nonachlor	trans-nonachlor	oxychlordane
Insect 1	ND	ND	ND	ND	ND
Insect 2	ND	ND	ND	ND	ND
Insect 3	ND	ND	ND	ND	ND
Insect 4	ND	ND	ND	ND	ND
Insect 5	ND	ND	ND	ND	ND
Insect 6	ND	ND	ND	ND	ND
Insect 7	0.0012	ND	ND	ND	ND

ND = Not Detected

Table 18. Continued

Sample	Heptachlor	heptachlor epoxide	Aldrin	dieldrin	endrin	mirex	PCB-Total
Insect 1	ND	ND	ND	ND	0.0014	ND	0.0102
Insect 2	ND	ND	ND	ND	0.0046	ND	0.0228
Insect 3	ND	ND	ND	ND	0.0029	ND	0.027
Insect 4	ND	ND	ND	ND	0.0030	ND	0.0281
Insect 5	ND	ND	ND	ND	0.0017	ND	0.015
Insect 6	ND	ND	ND	ND	ND	ND	0.0145
Insect 7	ND	ND	ND	ND	ND	ND	0.0317

Sample	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Total DDT
Insect 1	ND	ND	ND	ND	ND	ND	NC
Insect 2	ND	0.0072	ND	ND	ND	ND	0.0072
Insect 3	ND	0.0075	ND	ND	0.0056	ND	0.0131
Insect 4	ND	0.0055	ND	ND	0.0065	ND	0.0120
Insect 5	ND	ND	ND	ND	0.0043	ND	0.0043
Insect 6	ND	ND	ND	ND	0.0057	ND	0.0057
Insect 7	ND	ND	ND	ND	0.0052	ND	0.0052

ND = Not Detected
NC = Not Calculable

Table 19. Organochlorine concentrations (in µg/g wet weight) in fish collected on Quivira National Wildlife Refuge, 1996.

Sample	HCB	endosulfan II	alpha BHC	beta BHC	delta BHC	gamma BHC
Carp 1	0.0003	ND	ND	ND	0.0006	ND
Carp 2	ND	0.0009	ND	ND	0.0005	ND
Carp 3	0.0006	ND	0.0003	ND	0.0013	ND
Carp 4	0.0005	ND	ND	ND	0.0005	0.0004
Carp 5	ND	ND	ND	ND	ND	ND
Forage Fish 1	0.0015	ND	ND	ND	0.0005	ND
Forage Fish 2	ND	ND	ND	ND	ND	ND
Forage Fish 3	0.0003	ND	ND	ND	ND	ND
Forage Fish 4	0.0004	ND	ND	ND	ND	ND
Forage Fish 5	ND	ND	ND	ND	ND	ND
Forage Fish 6	0.0004	0.0006	ND	ND	0.0005	ND
Forage Fish 7	0.0003	ND	ND	ND	0.0005	ND

Sample	alpha chlordane	gamma chlordane	cis-nonachlor	trans-nonachlor	oxychlordane
Carp 1	0.0183	ND	ND	0.0019	ND
Carp 2	0.0364	ND	ND	ND	0.0013
Carp 3	0.0373	ND	ND	ND	ND
Carp 4	0.0174	ND	ND	ND	ND
Carp 5	ND	ND	ND	0.0012	ND
Forage Fish 1	0.0243	ND	0.0003	ND	ND
Forage Fish 2	0.0005	ND	ND	ND	ND
Forage Fish 3	ND	ND	ND	ND	ND
Forage Fish 4	0.0014	ND	ND	0.0005	ND
Forage Fish 5	ND	ND	ND	0.0005	ND
Forage Fish 6	ND	ND	ND	ND	ND
Forage Fish 7	0.0012	ND	ND	ND	ND

ND = Not Detected

Table 19. Continued

Sample	Heptachlor	heptachlor epoxide	Aldrin	dieldrin	endrin	mirex	PCB-TOTAL
Carp 1	0.0052	0.0006	0.0041	0.0007	ND	ND	0.0777
Carp 2	0.0031	ND	0.0064	ND	0.0016	ND	0.0841
Carp 3	0.0052	ND	0.0049	ND	ND	ND	0.0605
Carp 4	0.0009	ND	0.004	0.0009	ND	0.0004	0.0236
Carp 5	ND	ND	0.0022	0.0004	ND	ND	0.0183
Forage Fish 1	0.0058	0.0003	ND	0.0013	ND	ND	0.0348
Forage Fish 2	ND	ND	0.0005	ND	ND	ND	0.0045
Forage Fish 3	ND	ND	0.0037	0.0004	ND	ND	0.0507
Forage Fish 4	0.0013	ND	ND	ND	ND	ND	0.0284
Forage Fish 5	0.0004	ND	0.0008	0.0008	ND	ND	0.0295
Forage Fish 6	0.0011	ND	0.0004	0.0008	ND	ND	0.0521
Forage Fish 7	0.0003	ND	ND	0.0005	ND	ND	0.0241

Sample	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Total DDT
Carp 1	ND	ND	ND	0.0003	0.0028	0.0008	0.0039
Carp 2	ND	ND	ND	0.0008	0.0034	0.0023	0.0065
Carp 3	ND	ND	ND	0.0004	0.0032	ND	0.0036
Carp 4	0.0007	ND	ND	0.0007	0.0059	0.0013	0.0086
Carp 5	0.0004	ND	ND	ND	0.0029	0.0012	0.0045
Forage Fish 1	ND	ND	ND	0.0011	0.0042	ND	0.0053
Forage Fish 2	0.0004	ND	ND	0.0029	0.0184	0.0006	0.0223
Forage Fish 3	ND	ND	ND	ND	0.0009	ND	0.0009
Forage Fish 4	ND	ND	ND	ND	0.0014	ND	0.0014
Forage Fish 5	0.0005	ND	ND	0.0003	0.0021	0.0003	0.0032
Forage Fish 6	ND	ND	ND	ND	0.0030	ND	0.0030
Forage Fish 7	ND	ND	ND	ND	0.0044	ND	0.0044

ND= Not Detected

Table 20. Lipid and moisture content of invertebrate and fish samples collected on Quivira National Wildlife Refuge, 1996.

Sample	% Lipid	% Moisture
Carp 1	5.02	74.8
Carp 2	2.84	76.4
Carp 3	2.74	73.0
Carp 4	3.24	75.2
Carp 5	1.65	77.7
Forage Fish 1	5.04	75.8
Forage Fish 2	1.08	79.7
Forage Fish 3	2.08	80.2
Forage Fish 4	2.47	77.6
Forage Fish 5	2.94	81.2
Forage Fish 6	2.94	77.0
Forage Fish 7	2.72	78.0
Insect 1	2.65	78.3
Insect 2	1.94	73.4
Insect 3	6.87	53.9
Insect 4	7.65	50.2
Insect 5	9.18	37.8
Insect 6	7.97	55.2
Insect 7	10.70	41.9